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Full Spectrum

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Contents

I The Fundamentals

Spectrum — In Plain Language 3

"Frequency" Asked Questions 8

Electromagnetic Spectrum: Critical to our Nation's Security... 12

We Live in a Radiant World 16

A World Without Spectrum 20

Spectrum Isn't Like "Other Natural Resources" 23

Making Waves: Radio Spectrum a Vital Resource for Mission... 27

The Foundation of Future Spectrum 31

Becoming Wireless 38

The Choice Between Wired and Wireless 41

Electromagnetic Environmental Protection 45

Assessing Spectrum Supportability 48

The Four Stages to Addressing Spectrum Supportability 55

Ensuring Spectrum-Dependent Systems are "Up to Code" Saving... 59

Unlicensed Radio Frequency Devices 63

Host Nation Coordination: Assuring Spectrum Supportability... 69

Remarkable Professionals Ensure Command and Control of... 73

Strategic Directions in Spectrum Management 77

Electromagnetic Spectrum Performance Measurement Plan 85

II Full Spectrum

A Spectrum Management Perspective on Cell Phone Signal... 93
Rules create sharing between federal and non-federal radio... 96
Cross Banding: Enabling Communications Interoperability... 99
Electromagnetic Spectrum: Battleground in Warfare Dominance 103
Streamlining Real Estate Processes for Commercial Wireless... 106
Navy and Marine Corps: Good Neighbors in the Frequency... 111
Radio Frequency Congestion 115
DON Manages Increasing Spectrum Encroachment 118
Assessing the True Value of Spectrum 121
The Spectrum Sharing and Reallocation Dilemma 124
Spectrum Reallocation: Challenges and Opportunities 128
Increasing Spectrum Efficiency 132
How One Idea Can Change the World 135
International Spectrum Engagement 138
Policy Leads Innovation 144
Leveraging Lean Six Sigma 148
The DON Electromagnetic Spectrum Campaign 152
Transforming Spectrum Management 156
Plotting a Spectrum Revolution 160
Unmanning Unmanned Systems 164

A New Century for Unmanned Maritime Systems 169
Flocking, Herding and Schooling within Interconnected... 174
Radio 2050 177
The Evolution of Infrastructure 180
Spectrum Unification 184
The Road to Real-time Frequency Spectrum Sharing 187
National Radio Quiet and Dynamic Zones 192

Acknowledgement 195

I

The Fundamentals

Spectrum Basics
Spectrum-Dependent Systems
Spectrum Management

1

Spectrum — In Plain Language

This article takes terms commonly associated with electromagnetic spectrum and presents them in plain language and within context.

The full electromagnetic spectrum covers all man-made and natural electromagnetic waves, including radio, microwave, infrared, visible, ultraviolet, x-rays, gamma-rays. These electromagnetic waves are referenced by their frequency, measured in cycles per second or hertz (Hz). Earth naturally emits an extremely low electromagnetic resonant frequency of about 7.8 Hz. Gamma-ray waves have frequencies as high as 1024 Hz. This article addresses radio frequency spectrum, which begins below 10 kilohertz (kHz) and extends above 250 gigahertz (GHz).

Radio frequency spectrum is further subdivided into smaller sections called frequency bands. Frequency bands may be just a few hertz, such as the 100-Hz band between 19.95 kHz and 20.05 kHz used for standard frequency and time signals; or they may be many billions of hertz (GHz), such as the 217-226 GHz band, which includes radio astronomy frequencies.

Spectrum is a sovereign resource of every nation. Though many nations tend to allocate their spectrum similarly, there can be subtle and significant differences in how specific frequency bands are allocated because each nation can allocate spectrum as it sees fit for its requirements. Around the globe, radio frequencies are divided into hundreds of frequency bands. Some of these frequency bands are harmonized between nations, but others are not. For example, in the United States, the frequency band 7.2-7.3 megahertz (MHz) is used by amateur radio operators, but that same band is used by radio broadcasters in Europe, Africa and Asia. When the United States military is a guest in a host nation for testing, training, providing humanitarian support, or conducting other operations, it is required to operate its equipment in accordance with the host nation's spectrum allocations and laws. The United States recognizes that systems built to operate inside the United States may not have host nation coordination to operate in other countries. This is a crucial issue, and it is why it is imperative that our managers work with their spectrum managers for host nation coordination before deploying spectrum-dependent systems into their country.

The use allocated to a discrete frequency band is called a service. For example, Maritime Mobile, Meteorological Aids, Radiolocation and Radio Astronomy are all types of services; each identifies how spectrum is authorized to be used in each specific frequency band. Services are established and defined in the International Telecommunication Union's Radio Regulations.

A basic method of avoiding radio frequency interference is to limit certain services to specific frequency bands. For example, this approach assures high power radars in the Radiolocation service are not operating in the same frequency band, and overloading extremely sensitive radio telescopes operating in the Radio Astronomy service.

In parts of the world with high population density, including many areas of the United States, access to electromagnetic spectrum is exceptionally difficult. Electromagnetic spectrum is a finite natural resource. There is the same amount of spectrum today than there was before the invention of radio transmitters. New technologies must find space in the electromagnetic environment.

To manage these shortages, national and international regulators must occasionally change how electromagnetic spectrum is allocated to specific services within particular frequency bands. This is called reallocation. Reallocation enables the growth of a new technology, such as next generation mobile broadband, or expands the use of existing service, such as increasing the capabilities of the Aeronautical Mobile Service involving mobile communications between aircraft and ground stations.

Reallocation can be very expensive and can take a very long time. For example, some systems, such as satellites, are not easily updated to enable reallocation. The only option is to replace a system with new technology that meets the new allocation.

Relocating a device from one place in the spectrum to another has additional challenges. The new location must be suitable for the new system. For example, high or low enough in the frequency spectrum for the technology to work. Parts of the spectrum have different properties. Some electromagnetic waves that can "see" through rain while other waves bounce off the ionosphere. A system that relies on specific properties cannot relocate into another spectrum area with different properties.

In many countries, including the United States, before spectrum-dependent systems can be used the characteristics must be certified by the national spectrum regulators that the device will access spectrum within specified allocations and operate according to their national regulations. Within the United States, control of the electromagnetic spectrum is shared between the Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA). All manufacturers are required to obtain FCC certification before selling spectrum-dependent devices to the public. All federal government agencies are required to obtain NTIA certification before buying spectrum-dependent devices.

Certification can take a few weeks or several years depending on the complexity of the system, national spectrum allocations, and the intended use of the device. Military acquisition programs are always encouraged to seek spectrum management advice as early in development as practical. At a very minimum, spectrum certification must be completed prior to Milestone C, which initiates the production and deployment phase.

The NTIA regulates all spectrum users in the Executive branch of the government. These include: the National Science Foundation; National Aeronautical and Space Administration; Federal Aviation Administration; the military departments of the Army, Navy and Air Force; and other federal agencies such as the departments of Interior, Agriculture and Justice. NTIA assigns a frequency at a location for a specific purpose and use. This assignment is a federal agency's equivalent to an FCC license to operate. Assignments include parameters such as power, antenna height, radius for mobile operations, receiver location, and frequency.

The FCC regulates state, local and tribal government, commercial business and private citizen spectrum use. In Federal regulations, these are referred to as non-federal users. There are a few portions of spectrum designated non-federal exclusive, such as the 88-108 MHz band for FM radio broadcasting. There are also a few exclusive federal frequency bands, such as 14.5-14.8 GHz used for space research. However, nearly all electromagnetic spectrum in the United States is shared between federal and non-federal users.

Access to the electromagnetic spectrum is critical. There is continual activity in national and international forums to increase spectrum-dependent system efficiency, flexibility and adaptability and to assure optimum use of this valuable resource.

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2

“Frequency” Asked Questions

CHIPS magazine has hosted the authors articles about electromagnetic spectrum since 2005. This chapter presents some frequently or “frequency” asked questions from those articles.

What is Spectrum?

The electromagnetic spectrum, or “spectrum,” is all frequencies of electromagnetic waves. In the 17th century, spectrum referred to the frequencies, or colors, of visible light. Lower frequencies of the visible spectrum are red and higher frequencies are blue. By the end of the 19th century, scientists had discovered that the spectrum extended far beyond visible light. Above blue light they discovered ultraviolet and X-rays, and below red light was infrared and radio waves. Gamma rays were finally discovered in the early 20th century, in the highest part of the electromagnetic spectrum.

Where are radio frequencies in the electromagnetic spectrum?

Radio frequencies are a subset of the electromagnetic spectrum. Generally, the frequencies between 3 kHz and 300 GHz are referred to as the radio frequency (RF) spectrum.

Who owns the spectrum?

The electromagnetic spectrum is the resource of each country around the globe. Governments of every country establish a system to manage, protect and regulate the use of the spectrum within their borders.

Is anyone in charge of the spectrum?

Yes and no. The International Telecommunication Union – Radiocommunication Sector (ITU-R), an organization within the United Nations, establishes international radio regulations. This treaty like document is the foundation of radio frequency regulations in most countries including the United States. There are more than 190 member countries of the ITU-R. Since spectrum is a resource of each country, governments are free to regulate their spectrum in their best interest. While the United States adopts most of the ITU-R radio regulations, there is also United States regulation to satisfy unique requirements within our country.

Doesn't the Federal Communications Commission regulate spectrum?

Yes and No. Within the United States there are two bodies that coordinate the regulation and planning of the radio frequency spectrum — the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), an agency of the U.S. Department of Commerce. The FCC regulates non-federal use of the radio spectrum; including commercial, private citizens, state and local governments. The NTIA regulates federal government use of the radio spectrum, including the military departments.

What is spectrum management?

Broadly, spectrum management is: "The technical function where use of radio frequency spectrum is controlled to ensure the electromagnetic compatibility of communications-electronics systems." Spectrum management is performed at a number of levels including the International Telecommunications Union - Radiocommunication Sector (ITU-R), national spectrum management agencies like the FCC and NTIA within the United States, and locally like during natural disasters.

Which frequency band is most important?

Historically we relied on lower frequencies for communication because they travel long distances. However, in modern times there is no longer a specific frequency band that is the most important to the military. The preponderance of the frequencies used today are between 30 Hz to 30 GHz. The Extremely Low Frequency (ELF) band and Very Low Frequency (VLF) band travel through the earth and are used for submarine communications while higher frequencies in the Very High Frequency (VHF), Ultra High Frequency (UHF) and Super High Frequency (SHF) bands support voice and data communications. Frequencies in the EHF band support satellite communications that provide immediate, worldwide communications and intelligence capabilities.

Does we use frequencies higher than the EHF band?

Yes. Infrared frequencies are used in night vision cameras, visible light is electromagnetic spectrum, as are x-rays. However, these frequencies are not generally managed like radio frequency spectrum.

Why is the electromagnetic spectrum important to the DON?

The DON has a unique challenge among the military services since forward deployed Marine Corps forces and the fleet do not have direct access to commercial or military communications systems via landline. The only access to vital communications for forward deployed and at sea forces is via wireless links.

To ensure the Marine Corps and Navy have capable, reliable wireless communications, a broad range of the spectrum is required to support the diverse functions and global responsibilities of the naval services.

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3

Electromagnetic Spectrum: Critical to our Nation's Security and Economy

Increasingly, our lives, lifestyles, culture and economy depend on wireless devices. Wireless devices enable us to remotely monitor our sleeping children, turn on the television without leaving the couch, make phone calls whenever and wherever, pass through toll booths without stopping, and use our laptops and personal digital assistants virtually anywhere. These devices, and many others in our modern world, work because of the electromagnetic spectrum.

Electromagnetic spectrum, usually referred to as "spectrum", encompasses radio waves, infrared, visible light, ultraviolet light, x-rays, gamma rays and cosmic rays. Radio waves are an incredibly versatile area of the spectrum and make much of our modern communication possible, including television, AM and FM radio bands and satellite radio broadcasting. While spectrum makes our lives more enjoyable, it is, in fact, critical to our modern quality of life.

Modern health care depends on spectrum to operate medical monitoring systems. Public utilities use spectrum to remotely control pipeline valves that direct the flow of our water, electricity and gas. Transportation systems rely on spectrum for cargo tracking, air traffic control and security sensors.

Firefighters, police and emergency service personnel require spectrum for rapid communication, location positioning and other services. Additionally, spectrum allows manufacturers, shippers and merchants to monitor the location of products using advanced identification technologies, such as radio frequency identification (RFID).

War-fighter Reliance on Spectrum

Our Naval forces are especially reliant on spectrum. Using RFID technology, the Navy and Marine Corps track shipments of critical supplies and confirm patient identity and enter diagnosis and treatment information. In addition to implementing commercial technologies, our Naval forces have unique spectrum requirements. Communications; radar; air and fleet defense; weapons guidance; command and control; and many other systems rely on spectrum to function. In fact, conducting networkcentric warfare is impossible without spectrum.

Marine Expeditionary Forces, with integrated aircraft and combat service support, along with Navy SEAL teams, submarines and carrier strike groups are often the first to arrive in theater and must rely on spectrum to remain highly maneuverable, flexible and tactically effective.

An example of complex spectrum demand is found in a typical naval aircraft — voice communications and digital data links require many wireless devices. Weapons systems with associated fire control radar rely on spectrum for guidance to find and destroy their targets. Such demands have both expanded our military's need for, and increased its dependency on, spectrum.

The Challenge

A critical challenge is that spectrum is a finite resource, and it is in great demand. Without careful planning and implementation, spectrum-dependent systems may unintentionally, yet adversely interfere with each other. For example, a test flight at a naval air station was delayed because of interference to an important ground-based test measurement instrument. The source of the interference was a malfunctioning baby monitor in nearby military housing.

Providing balance between spectrum-dependent devices that make our lives more convenient and those that are critical to our national defense is a growing challenge. New technologies to improve wireless efficiency will be needed to maintain a balance between national defense and economic strength.

In the Department of the Navy (DON), we are constantly exploring technologies that allow us to utilize spectrum in innovative ways. Some of these technologies include: Frequency agile technologies that can sense a competing device on the same frequency and instantly switch to available spectrum; Software-defined radios that can set or alter almost any characteristic of a device, including frequency ranges and power and modulation, simply by loading new software; Ultra-wide band devices that can "see through walls" to detect combat threats without entering a building.

In addition to implementing new technology, we must all collaborate in the efficient use of current assets to guarantee dependable spectrum access for everyone.

Coordination of Spectrum Use

The complexity of spectrum coordination is enormous, and it is a global challenge because the DON deploys Marine Corps forces and Navy assets worldwide. Careful and constant coordination is required to guarantee that the Department meets it mission.

Through international negotiations, the DON ensures that the spectrum-dependent capabilities of the Navy and Marine Corps are preserved.

Because the radio frequency spectrum must be shared among nations, a United Nations agency, the International Telecommunication Union, convenes the World Radiocommunication Conference to modify spectrum allocation as technology and services require.

All members of the United Nations are invited to these conferences and the Department of the Navy Chief Information Officer participates as the Department's national and international representative to these forums.

To achieve its goals, the DON strives to improve efficient use of spectrum through collaborative efforts among business, industry, government and other nations.

In order to maintain America's advantage and secure our country's future, we must continue to work to meet our growing national spectrum challenges because electromagnetic spectrum is critical to both our nation's security and economy.

January-March 2007

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4

We Live in a Radiant World

Our atmosphere is filled with electromagnetic energy from many sources. These include man-made emissions from sensors and communications equipment, electrical power lines and generators, as well as natural emissions from lightning, the sun, cosmic radiation and other sources.

The electromagnetic environment is all around us every day. For example, electromagnetic energy from the sun reflects off the moon and refracts through the atmosphere to create the illusion of the harvest moon, the effect that makes the moon appear larger soon after the autumnal equinox.

Light is electromagnetic radiation. Energy arriving from the sun as infrared light warms the atmosphere, oceans and land. And when we sit in front of a campfire, we feel electromagnetic radiation, also in the form of infrared energy, warming our fingers and toes. Radio waves from the sun and distant stars can be heard as AM radio static, and on a stormy night that radio will crackle from the electromagnetic radiation released by lightning. We live in a radiant world with a very active electromagnetic environment.

Technology both impacts the electromagnetic environment and is susceptible to its negative effects. Electromagnetic energy can significantly affect Navy and Marine Corps capabilities and affect operations, training and safety. We all experience some of these effects when noise from our cell phones interferes with our music player. Those pulsating beeps and buzzing sounds are electromagnetic interference. But while cell phone noise may be a nuisance in our personal lives, electromagnetic interference to and from military systems can have significant effects on their operations.

It is critical that the Department of the Navy effectively manages and mitigates these negative effects during the planning, management and operation of installations, and during the construction and maintenance of their utilities infrastructure. In the future, as wires are replaced by wireless technology and our Sailors and Marines become more integrated into the Naval Networking Environment, the electromagnetic environment and its effects on systems must be associated with the performance attributes of emerging technology that are necessary to provide the operational capabilities required by the war-fighter.

Negative electromagnetic environmental effects can not only degrade the performance of systems, but they can also place personnel at risk, damage equipment, or even trigger catastrophic events such as the unintended detonation of ordnance or the ignition of fuels. Unless the electromagnetic environment is considered during research, development and acquisition, these effects can also increase the life cycle costs of weapons systems, automated information systems, and other systems that are instrumental to the success of the Sailors and Marines who are carrying out the DON’s mission.

The Department of the Navy continually strives to identify, understand, address and mitigate electromagnetic environmental effects to accomplish its warfighting missions. Because we live in a radiant world, we must all strive to minimize our impact on the electromagnetic environment and its impact on us.

It is DoD policy that:

- All electrical and electronic systems, subsystems, and equipment, including ordnance containing electrically initiated devices, shall be mutually compatible in their intended electromagnetic environment (EME) without causing or suffering unacceptable mission degradation due to Electromagnetic Environmental Effects (E3).
- Identification of requirements for E3 control shall be initiated early during the concept refinement and technology development phases, fully defined prior to Milestone C, and verified throughout the acquisition process. Pertinent documents such as Capability Development Documents (CDDs), Capability Production Documents (CPDs), equipment specifications, Information Support Plans (ISPs), and Test and Evaluation Master Plans (TEMPs) shall specify, define, and verify E3 control requirements, as appropriate.
- Operational effectiveness and suitability of all DoD weapons, command, control, communications, intelligence, surveillance, reconnaissance, and information systems in the intended operational EME shall be demonstrated.
- E3 issues shall be identified and assessed prior to entering the Systems Demonstration and Production and

Deployment phases and shall be addressed during critical design reviews. TEMPs shall include within the scope of critical operational issues and sub-issues, the requirement to demonstrate the effective E3 control of systems, subsystems, and equipment.

- The operational electromagnetic compatibility disposition of systems, subsystems, and equipment shall be reported in the ISP or in other management/support plans.
- Hazards of Electromagnetic Radiation to Ordnance (HERO), Hazards of Electromagnetic Radiation to Personnel, and Hazards of Electromagnetic Radiation to Fuel shall be mitigated prior to the conduct of all military exercises, operations, and activities.

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5

A World Without Spectrum

Imagine a world without wireless devices: no radios, no televisions, no radar or satellite systems, no key-less car locks, and no cell phones. Except as the plot of a low budget "B" science fiction movie, this isn't something most of us could imagine. But what would the world be like without radio frequencies?

The RF spectrum is where nearly all commercial and military electromagnetic spectrum dependent systems operate. RF is the workhorse of the electromagnetic spectrum. Generally, RF is categorized as those frequencies between 3,000 and 3,000,000,000,000 hertz. It is unimaginable how modern civilization could survive without RF. Could the Navy and Marine Corps successfully conduct 21st century operations without RF?

To fully appreciate how RF is integrated into our lives, businesses, and our national security, we must imagine a day without RF. Forget about waking to a clock-radio playing music or the local news; the radio would be nonexistent without RF. Traditional over-the-air television, as well as cable

TV, would also be out of service since both rely in part, or in whole, on RF frequencies.

The morning weather forecast is important to many people, and while we might think that we could simply use other media, such as newspapers, to provide daily weather forecasts, meteorologists heavily use RF for critical weather forecasting tools such as Doppler radar, weather satellites and remote wireless weather sensors. Without RF, the weather forecast would be much different. For example, on Sept. 8, 1900, more than 6,000 men, women and children lost their lives when a hurricane tore across Galveston, Texas. Advanced satellite capabilities were not available yet, and the storm came with little warning. Accurate predictions of when and where rain or snow will fall would be nearly impossible because satellite weather images would not be attainable.

As we go through our day without RF we would not have: automobile or satellite radios; the Global Positioning System (GPS); cell phones; traffic cameras (they are wireless); radar speed guns; or police radios. And while the absence of radar speed guns may be appealing to some people, imagine no radios enabling emergency services. Modern emergency response systems would be crippled without RF. In the first decades of the 20th century, police, fire and ambulance personnel could take hours to respond to an emergency. Without radio, public safety officers relied on primitive telephone call boxes to communicate. It wasn't until the 1930s that cities began to install two-way radios in police cars.

RF was a new technology when the Navy began broadcasting to ships in 1904, and this use of RF dramatically enhanced afloat safety. Today, the Navy and Marine Corps rely heavily on RF-dependent and RF-enabled capabilities. Thankfully, a sudden and total loss of RF is not likely. But, a new and increased use of spectrum worldwide is challenging the Department of the Navy's (DON) ability to ensure worldwide spectrum access and use for the Navy and Marine Corps. As a result, vital naval capabilities can be impacted due to increasing spectrum use by host nations.

Spectrum congestion in many areas of the world has reached a point where host nations are reallocating spectrum that once supported U.S. naval forces, to now support their own commercial and public use. The issue is serious, and the DON has implemented a number of requirements for the acquisition of spectrum-dependent equipment to attain the highest possible assurance that naval RF requirements are retained. These requirements address "spectrum supportability" and are mandated in DON as well as Department of Defense acquisition and spectrum management instructions.

Like a sci-fi movie where mankind is often complacent of the impending crisis, so too have we become complacent of our dependence on RF spectrum. The future of naval operations will include systems that are reliant on RF. And while we will never experience a day when RF stops working, we see too many days where critical RF systems are unusable because the DON does not have access to this vital resource. The DON CIO is engaged in strategic spectrum management to continually examine its dependency on RF investments in spectrum supportable systems and technology.

July-September 2010

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6

Spectrum Isn't Like "Other Natural Resources"

For the past 30 years the use of radio frequencies has dramatically increased. Radio has enabled the unprecedented growth of technology from cellular telephone to high speed wireless Internet. These and other capabilities we take for granted can only exist with the use of radio frequencies from the electromagnetic spectrum. However, a direct consequence from three decades of increased spectrum use is that spectrum availability, in many areas of the world, has declined to the point that spectrum is considered to be in short supply. The electromagnetic spectrum is generally regarded as a natural resource of the nation where it is used.

Spectrum has often been referred to as the "fuel" for wireless technology and the "oxygen" of the Internet. Spectrum differs greatly from natural resources, such as coal, land, water and air, because these resources are finite commodities; there is a limited amount of water, air, coal and land. Because they are finite resources, renewing them is either impossible or incredibly difficult. But the electromagnetic spectrum is not a finite commodity; it cannot be exhausted, and most importantly, the electromagnetic spectrum is instantly renewable. The moment that a radio, radar or some other spectrum-enabled device stops using a radio frequency, that radio frequency becomes instantly reusable by some other device. This simple, yet remarkable, difference means that efforts to manage and conserve the electromagnetic spectrum as if it were a natural resource, like water and land, are often misguided or ill-conceived. A resource that is instantly renewable cannot really be in short supply. As such, spectrum conservation is a misnomer.

The radio frequency spectrum includes all frequencies between 3 kilohertz (kHz) and 300 gigahertz (GHz). Except for the radio frequencies someone else is operating on at that precise moment, the entire electromagnetic spectrum is available for use 24/7.

Curtailing or minimizing the use of spectrum to conserve it for future use may make conservation minded people feel better, but it provides no preservation benefits whatsoever. Unlike natural resources that cannot be instantaneously recycled, spectrum is not physical; it cannot be saved for later use. The electromagnetic spectrum should be considered as an abstract resource.

Time is another abstract resource which cannot be stored and conserved. If time is not put to good use every moment, time is wasted. The same is true of the electromagnetic spectrum. Whenever spectrum is not used, it is a lost opportunity.

The U.S. radio frequency spectrum is allocated among federal and non-federal services, and use is governed by different organizations. The International Telecommunication Union, an agency of the United Nations, regulates information and communication technology issues. For nearly 145 years, the ITU has coordinated the shared global use of the radio spectrum, promoted international cooperation in assigning satellite orbits, worked to improve telecommunication infrastructure in the developing world and established worldwide standards. International spectrum governance involves the allocation of radio frequency bands for specific purposes and assigns radio frequencies for individual, commercial and government use.

This allocation and assignment strategy was conceived a century ago. Regrettably, this allocation and assignment policy restricts the efficient use of spectrum by limiting the use of a given radio frequency to a specific person, organization and/or purpose. Because the use is restricted, most radio frequencies are not used anywhere close to their full operational potential. Policy can be changed and with a new understanding of spectrum as an abstract resource, there is hope for future governance that permits the use of unused radio frequencies.

Understanding that spectrum is instantly renewable, that it can't be stored, and is being wasted every moment it is not used, the Department of the Navy is supporting emerging technology capable of using all available spectrum all the time. Technology under development known as cognitive radio systems will provide a dynamic spectrum access ability to identify and use unused radio frequencies. Cognitive radio systems capabilities will dramatically increase the effective and efficient use of radio frequencies by using more spectrum than is used today and simultaneously minimize the possibility of radio frequency interference.

As long as spectrum is defined as fuel for wireless technology, the oxygen of the Internet or prime real estate, it will likely be mismanaged as a finite resource. We are not running out of spectrum but, like time, spectrum that goes unused is wasted.

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7

Making Waves: Radio Spectrum a Vital Resource for Mission Success

We live in a radiant world. Natural cosmic and man-made radio waves flood the atmosphere around the world on a daily basis. These invisible and quiet waves are an important and integral part of our lives. Most people are heavily dependent on them to communicate with others, access electronic devices, and operate remote-controlled technology.

The entire electromagnetic spectrum cannot be seen by the human eye — only visible light is detectable. An electromagnetic field is generated when an alternating current is input into an antenna. Created by vibration or oscillating electric and magnetic fields, electromagnetic radiation consists of a stream of photons traveling silently in the form of waves moving at the speed of light. The electromagnetic spectrum cannot be heard. A wave is called electromagnetic because it is made up of two parts: an electric field and a magnetic field.

The only difference between the various types of electromagnetic radiation is the amount of energy generated. Radio waves have photons with low energies, microwaves have a little more energy than radio waves, and infrared light has still more energy. Moving up in energy level is visible light, ultraviolet light, X-rays, and the most energetic of all, gamma rays. The higher the radio wave frequency, the shorter its wavelength and the greater its energy.

As energies travel, they produce a unique wavelength with a frequency that can be identified and measured. Frequency is measured in hertz while wavelength is measured in meters. A wavelength is the distance from crest to crest between two peaks of a wave. A frequency is the time interval between passing peaks. The greater the length of the wave, the lower its frequency and energy will be. The shorter the wave, the higher the frequency and energy will be.

Radio waves have the longest wavelengths in the electromagnetic spectrum. These waves can be longer than a football field. The longest waves are several kilometers in length. The shortest radio waves are millimeters long while gamma rays measure less than the diameter of an atom. The radio frequency (RF) spectrum has several unique properties.

- Spectrum is free; it does not cost anything to use it.
- Spectrum is finite; there is a great deal of competition and demand for it.
- Spectrum is not consumed or destroyed when used.
- Spectrum is wasted when it is not being used.

RF spectrum is a vital and limited national resource, and the U.S. federal government makes extensive use of it for electronic communications and transferring data and information.

The use of the RF spectrum is regulated. Access is controlled and rules for its use are enforced because of the possibilities of interference between uncoordinated uses. Managing the RF spectrum can be a great challenge. Internationally, it is allocated by the International Telecommunication Union (ITU) to various classes of service according to different regions of the world. Within the United States, the RF spectrum is further allocated between non-federal government and federal government users.

The Federal Communications Commission (FCC), acting under the authority of Congress, is responsible for the allocation and assignment of frequencies to non-federal government, civil and commercial users, as well as state and local government agencies. The FCC decides who is able to use specific frequencies for specific purposes, and it issues licenses to stations for specific frequencies.

The National Telecommunications and Information Administration (NTIA), which is an operating unit of the Department of Commerce and an Executive Branch agency that is principally responsible for advising the president on telecommunications and information policy issues, administers the allocation and assignment of frequencies to departments and agencies of the federal government such as the Department of the Navy, Federal Aviation Administration and the Federal Bureau of Investigation.

Coordination between non-government and government users of the RF spectrum is accomplished by joint meetings of the FCC and the NTIA. The NTIA is also responsible for maintaining the National Table of Frequency Allocations. The NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management is the guidebook for frequency authorization in the United States, its possessions and territories.

The use and access of the radio spectrum are fundamental to the government, military and war-fighter to accomplish core missions across all functional and operational areas. The military is heavily dependent on the RF spectrum to communicate essential and urgent information and data instantaneously.

The government and military are required to manage the spectrum by planning, coordinating and managing the use of the RF spectrum through operational engineering and administrative procedures, policies, standards and directives. The objective is to enable spectrum-dependent equipment and capabilities to perform their functions in the intended electromagnetic operational environment while avoiding harmful RF interference.

The future role of the United States as a superpower and its assured victory in conflicts are dependent on how it makes use of the electromagnetic spectrum, and how it commands and controls this valuable, finite, congested and contested natural resource.

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8

The Foundation of Future Spectrum

The radio frequency electromagnetic spectrum is more important to the Department of the Navy (DON) today than it has ever been in the more than 100-year history of radio.

As the diversity of spectrum applications grows, the complexity of obtaining spectrum support grows accordingly. Along with engineering, coordinating and managing the tens of thousands of frequencies used in today's complex radio systems, Navy spectrum managers also use and maintain a wide array of databases. Without them it would be impossible to reliably operate radar, telemetry networks, microwave data links, mobile radios or anything dependent on a frequency in the electromagnetic spectrum.

Automated networkcentric spectrum management tools of the future will rely on these databases, as cognitive radios of the future autonomously adapt to meet the needs of a dynamic battlefield. Highly accurate and up-to-date databases are the foundation of future spectrum management.

Two Fundamental Types of Databases

There are many sources for information used in spectrum management including national and international radio regulations, maps and geodetic information, propagation studies, sunspot numbers and more. At the core of spectrum management are two fundamental types of databases. The first contains documents detailing what equipment characteristics are certified and authorized for use within the United States, its possessions and host nations in which the DON operates.

The second database contains detailed licensing information of how individual radio frequencies are assigned for use within the United States, its possessions and host nations around the world. When these two databases are combined, they form the picture of not only how the DON uses the electromagnetic spectrum today, but also what portions of the electromagnetic spectrum are available to meet requirements in the future.

Equipment certification defines how a spectrum-dependent device may operate within the electromagnetic environment. Detailed data are registered, defining all the characteristics of the transmitter, antenna and receiver. Usually a transmitter is capable of more power, features or greater bandwidth than the spectrum can support everywhere the DON operates. This is why the database also includes information about how the system is authorized to operate.

Limitations may vary from location to location and country to country. Certification of spectrum-dependent devices can begin as early as the conceptual stage of development. As a device is developed, the spectrum community is able to provide the guidance necessary to successfully operate the system in the congested, highly regulated radio frequency spectrum environment. Restrictions are also defined in the certification database to assure that operations abide by local, national and international radio regulations.

Frequency Assignment

Frequency assignment is the licensing of an individual radio frequency in a particular geographic area. The assignment database lists detailed parameters that define the electromagnetic radiation from an antenna. These parameters include the maximum power authorized from the transmitter, the maximum antenna height, the amount of spectrum occupied by the transmitted signal and the type of modulation used.

In addition to the technical characteristics of the signal, the assignment databases also contain administrative information about who is authorized to use the frequency, under what conditions it may be used and what equipment is authorized to transmit. When combined, the equipment and frequency databases contain nearly all the information needed to determine the characteristics of the electromagnetic spectrum-dependent devices that the DON operates, at any time and in any place.

Years ago, radio frequency spectrum management was done with mechanical slide rules, formulas, best guesses, rules of thumb and hours or sometimes days of labor to predict characteristics of the electromagnetic environment. Cognitive radios that continually reprogram themselves to maximize the local spectrum must do all this and much more in less than the blink of an eye. Success depends not only on the advanced technology of future radio systems, but also on today's spectrum manager updating and maintaining an accurate database.

Net-centric spectrum management uses the information in the equipment and frequency databases to dynamically model the spectral environment while software-defined cognitive radios will determine the best frequencies and transmission parameters to complete communication. With accurate information, the next generation of spectrum management automation tools will model and predict the electromagnetic environment. The accuracy of these predictions depends entirely on the accuracy of the databases. Therefore database accuracy is essential.

Many of today's spectrum records are decades old and not detailed enough to support the electromagnetic demands of future radio systems. The engineering tools may not have been available, or the level of detail was not required for equipment certification and frequency assignment when the system first entered the inventory. Some transmitters have been in operation for nearly as long as there has been spectrum management.

In 1952, the U.S. Navy built a very low frequency transmitting station located at Jim Creek, in Oso, Wash., and it is still in operation. On the other hand, many modern systems are so complex they do not conform to the current certification and assignment processes. Nevertheless, the DON spectrum management community is actively engaged in aggressively updating and validating all spectrum-related databases.

Frequency Reviews

Radio frequency assignments are generally reviewed at least once every five years. During the review process a spectrum manager evaluates all electromagnetic parameters of the system and compares it to the data in the record to verify it is accurate. The five-year review process is also an opportunity to add data omitted from the original application or update data which may have changed. Even small data errors such as incorrect latitude or longitude for transmitters or receivers, erroneous antenna heights or terrain elevation can all result in frequency assignments that cause interference with another system. The frequency assignment is the license that authorizes the DON to transmit, and it must be accurate at all times.

There are no periodic reviews of equipment certification. However, whenever there are modifications or upgrades, they are added to the certification. Also, when the associated frequency assignment is reviewed, spectrum managers review the equipment certification. New capabilities or modifications to the equipment are recorded along with any administrative changes. Sometimes, new restrictions or rules regulating operation are also added. Occasionally equipment replacement or upgrades require the spectrum manager to submit new documentation requesting certification of new equipment recently added to the inventory.

The DON is one of the federal government's largest users of the electromagnetic spectrum. The Department's interest in the electromagnetic spectrum is straightforward — ensuring spectrum access for the U.S. Navy and Marine Corps. Access to frequencies for required training, day-to-day support and operations is a paramount concern and a priority endeavor of the DON. Given the fact that spectrum reallocation, policy determinations and new allocations all have serious consequences for the DON, it is in the Department's best interest to be as good a steward as possible in our use and management of spectrum.

Thanks to a dedicated group of professional spectrum managers working in the fleet, ashore and throughout the chain of command, the Department of the Navy will be ready with a strong foundation to build the future of spectrum management.

What has the DON CIO Spectrum Team Done Lately?

Participating in National Telecommunications and Information Administration (NTIA) working groups and coordinating with DoD to formulate a consolidated DoD position for development of the Presidential Strategic Plan for Electromagnetic Spectrum Management.

Developing a Land Mobile Radio policy in conjunction with ASN (RDA), HQMC C4 and OPNAV N46 for effective emergency communications. It will establish standards for encryption and interoperability within the DON.

Worked with the DoD and the Federal Communications Commission to resolve a consumer garage door radio frequency interference issue by locating new frequency assignments for garage door openers away from the frequency used by first responders near Camp Pendleton, Marine Corps Base Quantico and Navy Region Northwest.

Sponsored and led the introduction of DON XML Naming and Design Rules (NDR) into the Afloat Electromagnetic Spectrum Program (AESOP) software upgrade. The NDR-compliant version of AESOP proved so successful during Trident Warrior 2004 exercises that the Chief of Naval Operations recently mandated its use in all communications and radar planning.

Led a Department of State delegation at the Inter-American Telecommunication Commission meeting in Argentina – a coalition of 35 countries from the Americas that collaborate on spectrum policy and use issues. As a result, the DON will be included in U.N. treaty negotiations, which will ensure that the Navy's equities are protected and that warships can operate with impunity.

As an international chair of the International Telecommunication Union (ITU), identified the need for and initiated a global study to recommend technical standards to protect maritime communication systems.

As the DoD representative, worked on developing the U.S. position on the technical, operational and regulatory provisions regarding the use of spectrum by space services to reduce the risk of encroachment and reallocation into DoD-designated frequency bands.

Rallied Australia, Russia and the Arab States at the U.N. proceedings in Geneva to oppose a European proposal to reserve certain frequency spectrum bands, thereby preserving the maritime mobile allocation for the DON's continued use.

Coordinated more than 570 radio frequency assignments for the DoD in support of Hurricane Katrina relief operations. This included coordination between the DON CIO, OPNAV, HQMC and the Navy Marine Corps Spectrum Center.

October-December 2005

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=3189

9

Becoming Wireless

In April 2008, the Department of the Navy Chief Information Officer (DON CIO) released a report called "Department of the Navy Enterprise Mobility 2008." This concise report describes the strategy the DON would use to leverage the significant advantages that commercially available wireless technologies can deliver to our war-fighters and those who support them. The report is available for download on the DON CIO Web site at www.doncio.navy.mil under the products link.

Enterprise mobility affects everyone and everything, everywhere across the DON. Though it may be less obvious for some of us than for others, we are all dependent on technology that connects to either a wired or wireless infrastructure. One of the department's greatest strengths is the interconnection of people and processes. Because of its unique mobility requirements, the DON has many more wireless connections than our civilian counterparts in industry.

As we move into the second decade of the 21st century, even more of these connections will become wireless. Before we enter the third decade, enterprise mobility through wireless technology will expand access to information wherever warfighters are located, regardless of the existence of a wired infrastructure.

However, all wireless technologies have inherent drawbacks and resultant concerns. Some of the key concerns are described below.

Information Assurance

Can the traffic be intercepted and read by an adversary or easily jammed, thereby preventing information from getting through? This is particularly important as classified voice and Secure Internet Protocol Router Network (SIPRNET) communications will increasingly utilize wireless transport modes.

Interference

Will introducing new radio frequency emanations into a military environment negatively impact existing systems? Interference can hamper communications, degrade the performance of collocated electronics, or even cause ordnance to malfunction, an effect called Hazards of Electromagnetic Radiation to Ordnance, or HERO.

Robustness.

Will the solution work across settings? For example, different frequencies have different propagation characteristics; what works well in a wide open environment may not work nearly as well in a shipboard environment with its numerous metallic enclosed spaces.

Non-standard spectrum allocation

Differing spectrum assignments in some countries mean that some equipment cannot be used globally unless there is permission to operate from the host nation.

Implementation of wireless technologies cannot go forward until these potential drawbacks are satisfactorily addressed. Department of the Navy Enterprise Mobility 2008 describes the strategy the department is following in assessing and adopting commercially available wireless products.

To establish a governance framework and information repository to enable deployment of secure, interoperable, cost effective and capability enhancing wireless architectures, the DON CIO chartered the DON Wireless Working Group (DWWG) for Enterprise Mobility under the DON Information Executive Committee. The DWWG is a problem-solving forum. It makes recommendations to the DON Information Executive Committee regarding wireless solutions and strategies suitable for enterprise application.

The DWWG is a critical component of the department's efforts to minimize and manage the risk involved in introducing new technologies to the DON technical architecture. Since it was chartered in 2005, the DWWG has published policy and guidance and continually works to align wireless opportunities and capabilities with mission needs and DON deficiencies.

January-March 2009

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2710

10

The Choice Between Wired and Wireless

Whether wireless voice, video or data, the number of wireless applications is increasing. Wireless capabilities can be as simple as a wireless doorbell system or as complex as a naval unmanned aerial system providing real-time intelligence to forward-deployed Marines and Sailors.

While the use of wireless systems is certainly advantageous for mobile requirements, wired systems retain a number of inherent benefits for non-mobile, transportable or nomadic requirements.

Both wired and wireless connectivity have advantages and disadvantages that should be evaluated whenever new capabilities are considered. “One Size Fits All” is not a solution for every Navy or Marine Corps requirement.

Wired and wireless solutions each possess inherent risks and benefits that should be considered whenever a transmission medium is selected. And while some risks and benefits are obvious, others are not immediately apparent until a thorough comparison of capabilities, benefits, risks and rewards is made.

Cost

Cost benefits associated with wired and wireless transmissions were often dramatically different a decade or more ago. A copper "wired" solution was generally less expensive than many wireless capabilities, while fiber optic and its associated equipment were generally more expensive than wireless systems.

However, these broad rules of thumb no longer apply. Recent technological developments and production capabilities have significantly reduced the cost of wireless and fiber optic equipment.

Determining the "best buy" for wired or wireless systems now requires consideration of installation requirements and associated costs, as well as maintenance requirements and technology refresh costs.

Accordingly, the total cost of ownership must be developed to determine the most economical transmission media to support connectivity requirements.

Security

Security risks must be an upfront driver for determining wired or wireless use. Security considerations include cryptographic requirements and information assurance (IA) requirements.

Additionally, physical security requirements, including access to transmission lines or transmission points, such as towers, antennas and associated equipment, must be considered.

Depending on the capability requirement, security issues may be complex. Wired and wireless transmission media have previously been chosen with little if any security considerations.

However, today’s digital capabilities generally necessitate layered security measures to ensure networks and standalone systems are protected from physical, as well as internal and operational damage.

Potential information compromise must also be considered when addressing security issues. It may not be easy to determine the best alternative between wired and wireless due to unique security issues among voice, video and data transmissions.

Wireless operations are generally thought to have greater security concerns than wired operations due to radio propagation characteristics; however, both mediums are susceptible to intrusion if security issues are not adequately addressed.

Reliability

All Department of the Navy voice, video and data requirements include mandates for reliable solutions that minimize downtime. Downtime not only results in service loss to users but also increases maintenance and reinitiation activities.

A number of factors affect system reliability including environmental, electrical and maintenance issues, in addition to other considerations. Reliability, in many ways, is similar to system security; reliability can be impacted by issues that appear insignificant or are overlooked.

While wired systems may seem to offer the greatest reliability, they are subject to vulnerabilities that wireless systems are not. Some common issues that often impact the reliability of wired systems are severe weather conditions, which can destroy cables, or digging equipment and tracked vehicles, which can cut cables.

Wireless systems have intentional and unintentional radio frequency interference vulnerabilities as well as signal coverage challenges.

The Navy and Marine Corps will continue to use both wired and wireless systems for communications, intelligence and other naval requirements.

The choice between wired and wireless, given the option, is not an easy or obvious decision.

July-September 2009

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?ID=2648

11

Electromagnetic Environmental Protection

Much like the Industrial Revolution led to increased awareness of land, air and water pollution, the wireless revolution is creating an awareness of electromagnetic pollution. The electromagnetic environment (EME) is all around us, and failure to protect it from pollution could affect departmental operations.

Access to the electromagnetic spectrum is critical to the Department of the Navy (DON). A typical Navy carrier battle group uses as much spectrum as a medium-sized city, including an airport. While the DON is committed to protecting the EME, preventing and identifying situations that might be considered pollution is a challenge.

The DON is concerned about protecting the EME for the same reasons it protects air, water and land. Maintaining a sustainable EME has ecological, economic, political and cultural dimensions in much the same way maintaining our waterways for commercial and recreational use while providing safe drinking water does. There is increasing concern about the effect the exponential growth in wireless activity could have on the EME.

The EME is simultaneously a natural and a man-made environment. Whether the EME is considered a natural resource or physical phenomenon, it is critical that the DON consider its effects on all DON mission areas.

Maintaining a balance between security and economic demands for spectrum depends on a sustainable EME, and a sustainable EME requires the DON to balance national defense and commercial demands with fair and equitable access. In some ways, sustaining the EME requires strategies similar to noise abatement. While few people would wish to live near an airport, most agree they are necessary for modern life. Noise abatement rules protect the community environment while maintaining commercial access to air travel.

There are, however, many barriers to enforcing electromagnetic environmental protection policy. For one, those negatively affected by electromagnetic pollution may not be able to locate the source; unlike water, air or land, electromagnetic pollution is invisible, and the effects may not be apparent to the polluter.

In recent years the EME has begun to receive significant media attention and political interest. Spectrum shortages have raised electromagnetic environmental protection to near-crisis status in geographic areas where the DON and local communities are encroaching on each other's spectrum. Some EME issues are unique to the local camp, post or station, and are challenging to address in departmental policy. But local challenges are being resolved through the hard work and dedication of Navy and Marine Corps installation spectrum managers. DON spectrum managers answer to various groups, compete for resources and mitigate a wide array of potential harms to the EME.

However, it is impossible to address EME protection effectively or efficiently if there is no specific mission requirement. Secretary of the Navy Instruction 2400.2 identifies who is responsible for electromagnetic environmental policy and management, but the broader concept of EME protection is still developing.

April-June 2014

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=5020

12

Assessing Spectrum Supportability

The electromagnetic spectrum is a critical enabler of the Department of the Navy's ability to communicate and operate in a global environment. More than ever before, deployed Sailors and Marines depend on the electromagnetic spectrum because it enables nearly all Navy and Marine Corps capabilities, including strategic command and control; tactical communications (airborne and ground); intelligence, surveillance and reconnaissance; and radar, navigation and weapons systems.

Spectrum is also important to world commerce because it enables a vast array of wireless capabilities, including e-mail, mobile telephone, and other capabilities that are now essential to modern-day business and life. While spectrum is a finite natural resource, it is readily available in most rural areas of the world.

However, spectrum is congested in major metropolitan areas which include many coastal regions of the world. As a result, spectrum can be challenging to acquire in some geographical areas of the world and easily acquired for use in others.

The ability of Navy and Marine Corps forces to support diverse missions is critically dependent on the availability of spectrum. This availability is determined by a number of varying factors, including a host nation's allocation and control of spectrum within its borders, congestion, and operational requirements of spectrum-dependent equipment and systems.

Due to diverse and unique governance within many sovereign nations, spectrum-dependent systems and equipment procured for U.S. military use should be planned and designed for multi-band operation or provide significant tuning flexibility to maximize global use.

Spectrum supportability is an assessment of whether the electromagnetic spectrum necessary to support the operation of spectrum-dependent equipment or systems will be available when required. While assessing the spectrum supportability for equipment does not constitute the right to operate the equipment, it can identify whether equipment can be supported with spectrum.

Spectrum supportability is composed of a number of processes. Obtaining permission to operate spectrum-dependent equipment may involve a lengthy, multi-step process that should be started as early as possible. It begins with a Spectrum Supportability Assessment (SSA) and includes considerable coordination and scrutiny. The box above contains guidance for ensuring spectrum supportability.

Department of Defense Instruction (DoDI) 4650.01, "Policy and Procedures for Management and Use of the Electromagnetic Spectrum," requires all DoD components to conduct spectrum supportability risk assessments as early as possible in the procurement of spectrum-dependent systems or equipment.

The purpose of the risk assessment is "to affect design and procurement decisions" because the early identification of regulatory, technical and operational spectrum supportability risks minimizes the possibility that the spectrum-dependent equipment cannot be employed to support Navy and Marine Corps requirements. Identified risks should be reviewed during acquisition milestones for programs of record and throughout a system's life cycle.

Within the DON, the responsibility for conducting a Spectrum Supportability Assessment resides with the organization procuring or acquiring the spectrum-dependent system or equipment. The composition and level of complexity for conducting a SSA is dependent upon a number of factors including the type of spectrum-dependent equipment and the intended operational area.

While it is necessary to assess the supportability of all spectrum equipment intended for procurement, some equipment requires only completion of the SSA. This would generally include equipment that complies with the "non-licensed" requirements identified in the National Telecommunications and Information Administration's (NTIA) "Manual of Regulations and Procedures for Federal Radio Frequency Management" and for equipment that will not be used outside of the United States and its possessions (US&P).

Equipment of this type often includes wireless peripheral devices such as a wireless mouse or keyboard, wireless routers and Family Radio Service. Any spectrum-dependent equipment intended for use outside of the US&P, regardless of conformance with NTIA non-licensed requirements, is subject to DD Form 1494 – Application for Equipment Frequency Allocation requirements and applicable host nation requirements.

DD Form 1494 – Application for Equipment Frequency

Allocation

The DD Form 1494 – Application for Equipment Frequency Allocation is used to record the technical characteristics of spectrum-dependent equipment and apply for host nation coordination and host nation allocation. The technical information documented on the form includes transmitter power, bandwidth and receiver sensitivity. It also includes other data that is essential for the employment of the equipment, HNC/HNA requirements, and frequency requests and assignments.

Host Nation Coordination/Host Nation Approval

In peacetime, international spectrum governance requires military forces to obtain host nation permission to operate spectrum-dependent systems and equipment within a sovereign nation. International governance is honored and enforced by the U.S. departments of State, Defense and Navy. In wartime, international spectrum governance is not honored between warring countries; however, the sovereign spectrum rights of bordering countries must be respected by military forces executing their assigned missions.

Accordingly, HNA is solicited by U.S. naval forces to use spectrum-dependent systems and equipment in bordering countries' airspace and/or on bordering countries' soil. HNA must be obtained before the operation of spectrum-dependent systems and equipment within a sovereign nation. The combatant commander is responsible for coordinating requests with sovereign nations within his or her area of responsibility. Because the combatant commander has no authority over a sovereign nation, the HNC/HNA process can be lengthy.

U.S. Equipment Certification

Equipment certification is a U.S. HNC/HNA process. The NTIA coordinates and reviews equipment certification requests with the agencies of the federal government. U.S. equipment certification ensures that the radio frequencies required for the operation of the equipment can be made available within the United States. It also ensures that equipment that cannot be supported with a radio frequency is not purchased.

Electromagnetic Environmental Effects

The joint definition of electromagnetic environmental effects (E3) is: "the impact of the electromagnetic environment upon the operational capability of military forces, equipment, systems, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility and electromagnetic interference; electromagnetic vulnerability; electromagnetic pulse; electronic protection; hazards of electromagnetic radiation to personnel, ordnance and volatile materials; and [the] natural phenomena effects of lightning and precipitation static."

Before the acquisition of spectrum-dependent equipment, possible impacts of electromagnetic compatibility (EMC) and electromagnetic interference (EMI) should be considered to ensure the equipment can be employed in its intended operational environment.

In accordance with DoD Directive 3222.3, "DoD Electromagnetic Environmental Effects (E3) Program," "Identification of requirements for E3 control shall be initiated early during the concept refinement and technology development phases, fully defined prior to Milestone C, and verified throughout the acquisition process."

Frequency Request and Assignment

A frequency assignment provides authorization for operation of a spectrum-dependent system or equipment under specific requirements and generally applies to a specific geographical area. Frequency assignments must be requested before the operation of systems and equipment and authorized by a proper authority for a given geographical area.

Within the US&P, frequency assignments for use by federal agencies, including the DON, are authorized by the NTIA. Navy and Marine Corps requests for frequency assignments are coordinated with the NTIA under the authority of the DON Chief In¬formation Officer. Outside the US&P, regional combatant commanders authorize and assign frequencies within their area of responsibility; a sovereign host nation is the ultimate authority for use of radio frequencies within its boundaries.

Ensuring spectrum supportability for Navy and Marine Corps equipment and systems is often a complex task in light of global requirements. But despite the enormity of the challenge, the DON maintains a fully capable team of experts to assist and process applicable spectrum supportability requirements.

In addition to the Spectrum Supportability Assessment, spectrum supportability may include the completion of: DD Form 1494 – Application for Equipment Frequency Allocation; U.S. Equipment Certification; Electromagnetic Environmental Effects (E3) Assessment; Host Nation Coordination/Approval (HNC/HNA); Frequency request/assignment; and a Spectrum Supportability Assessment.

The Department of the Navy has established spectrum policy that aligns with international, national and DoD spectrum governance to attain access for all spectrum requirements of the Navy and Marine Corps.

January-March 2010

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2555

13

The Four Stages to Addressing Spectrum Supportability

Federal regulation and Department of Defense (DoD) and Department of the Navy (DON) policy require that spectrum supportability must be addressed before acquiring communications-electronics (CE) systems and equipment that require use of the electromagnetic spectrum (radio frequencies).

CE equipment of this type is generally referred to as being "spectrum dependent" and includes all radar, unmanned aerial systems, unmanned ground systems, radios, sensors as well as other equipment. The spectrum supportability requirement pertains to organizations, including program offices, commands or organizations, that intend to purchase or lease spectrum-dependent equipment.

Within the DON, the primary purpose for addressing spectrum supportability, besides being mandated by the Office of Management and Budget (OMB), is to ensure that DON spectrum dependent equipment can, in fact, be used by the Navy and Marine Corps.

Although the requirement to address spectrum supportability is clearly stated in many DoD and DON policies, including acquisition and spectrum management policies, the purpose of addressing the methods of determining spectrum supportability is often misunderstood. In general, spectrum supportability is an assessment to ensure a given system or piece of equipment can be supported with radio frequencies within the geographical area in which it is intended to operate.

The complexity of spectrum supportability is dependent upon a number of factors. In the case of spectrum-dependent equipment procured to support forward deployed naval forces, ensuring spectrum supportability is operationally critical to the warfighter.

Ensuring worldwide spectrum supportability is certainly more complicated and requires more lead time than ensuring spectrum supportability solely within the United States. However, since the Navy and Marine Corps conduct training as well as day-to-day sustainment, addressing spectrum supportability within the United States is of no less concern. While the factors affecting spectrum supportability vary, the following provides an overview of the DON's spectrum supportability requirements.

Within the DON, spectrum supportability documentation is initiated by the program office or procuring organization by completing an electronic "DD Form 1494." The form is used to document the technical characteristics of the spectrum-dependent equipment such as the frequency or frequencies of operation, transmitter power and other information.

The acquisition of spectrum-dependent equipment or systems that are being developed by the Navy or Marine Corps requires the submission of a DD Form 1494 at four stages of development.

Conceptual (Stage-1) is submitted as early as possible within the development effort.

Experimental (Stage-2) is submitted before the development of any prototype version of the system or equipment. If supportable, the approval of a Stage-2 1494 generally authorizes limited production for research and experimental purposes. An experimental 1494 should be submitted before Milestone B.

Developmental (Stage-3) is required by Milestone C and generally authorizes an increase in production, providing that a positive spectrum supportability determination has been made.

Operational (Stage-4) is submitted before full production. The acquisition of commercial-off-the-shelf (COTS) and non-developmental item (NDI) spectrum-dependent equipment or systems by the Navy or Marine Corps generally begins with the submittal of a Stage-4 1494.

The federal government is transitioning to a Web-based Federal Spectrum Management System (FSMS) developed by the National Telecommunications and Information Administration (NTIA). During the development of FSMS, the NTIA is introducing the Equipment Location-Certification Information Database (EL-CID), which will eventually replace the DD Form 1494 process. The latest release of EL-CID is available for download from the NTIA at www.ntia.doc.gov/osmhome/elcid/.

Within the DON, the Navy and Marine Corps Spectrum Center (NMSC) provides support to Navy and Marine Corps organizations addressing spectrum supportability. Additionally, all systems commands within the naval services have personnel with spectrum supportability expertise. The NMSC can provide these points of contact upon request.

April-June 2008

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2812

14

Ensuring Spectrum-Dependent Systems are “Up to Code” Saving Time, Money

To achieve the most efficient use of communications-electronics (C-E) resources, the required capabilities of systems and equipment should be met during the procurement phase rather than investing in equipment that may require redesign or retrofitting after development.

Therefore, it is more critical than ever in these budget constrained times that program offices and procuring officials take advantage of processes that ensure systems and equipment provide their intended capabilities with minimal rework.

The use of electromagnetic spectrum, or radio frequencies, is a common wireless enabler for many, if not most, new C-E systems. The proliferation of wireless spectrum use within the Department of the Navy continues to increase. As a result, access to electromagnetic spectrum for all wireless systems is no longer ensured.

The electromagnetic spectrum is a scarce and highly regulated resource used around the world. Ensuring spectrum support for DON systems is a critical and necessary requirement that must be initiated during procurement and in the earliest stages of system development. Systems must be designed to operate in the proper spectrum, or they may interfere with other systems or violate international treaties and regulations. Retrofitting systems to bring them into compliance with regulations is often much more expensive than properly designing them from the beginning.

Spectrum supportability, meaning the availability of radio frequencies for a given system in its intended operating environment, must be ensured for C-E equipment that use radio frequencies. The term also describes whether a system's spectrum use is in compliance with local regulations and international treaties. While the term is regularly used within the Department of Defense's spectrum community, it is critical that it is understood throughout the DON's operational and acquisition communities, which procure and develop spectrum-dependent systems and equipment.

Spectrum supportability entails a number of factors that include the location in which the equipment will be operating and its compatibility with other equipment, as well as safety factors. The process to ensure a high degree of spectrum supportability begins early in the acquisition process. Organizations must complete and submit a spectrum supportability risk assessment and an application for equipment frequency allocation. This ensures compliance with international, federal, DoD and DON spectrum policy.

The information provided in the assessment and application is used by personnel within the federal government, departments of Defense and Navy, and host nations (nations that allow the

United States access to their spectrum) to provide guidance for the successful acquisition of spectrum-dependent equipment and to ensure radio frequencies can be made available within the equipment’s intended operational area. The completion and data requirements of the assessment and application are detailed in DoD Instruction 4650.01: “Policy and Procedures for Management and Use of the Electromagnetic Spectrum.”

These documents are similar to building permits. While building permits assess zoning, water, sewage and other factors that encompass building construction, the spectrum supportability documents are reviewed to determine potential effects on the electromagnetic environment, as well as compliance with applicable regulations, treaties and guidance. These evaluations are intended to ensure that radio frequencies can be acquired in the equipment’s intended operational area and that the use of the equipment will not degrade the effectiveness of other spectrum-dependent equipment in the same environment. Additionally, consideration must be given to a system’s electromagnetic environmental effects (E3).

E3 considerations include radio frequency interference and potential detrimental effects from its use on other electronics systems (RF dependent or not). Electromagnetic environmental effects can degrade the performance and operational capabilities of guidance systems, weapons systems and munitions. In some cases, environmental effects have the potential to cause catastrophic events.

An equally critical aspect of spectrum supportability is the DON’s requirement to be fiscally prudent with acquisition funds. The development or acquisition of spectrum-dependent systems that are not supportable wastes precious resources.

It is more than fiscally wasteful; it can result in the loss of necessary, and sometimes vital capabilities for the operational forces, which can heighten the risk of mission failure and injury. The need for efficient and effective use of funds cannot be overstated. The Office of Management and Budget requires agencies to ensure radio frequencies can be made available before estimates are submitted for the development or procurement of spectrum-dependent systems.

Just like building permits are updated to allow modifications, so too must spectrum supportability documents be regularly updated to remain current with acquisition and development changes. Updating spectrum data enables spectrum professionals to continually provide refined guidance to further ensure a system's spectrum supportability.

Completing and updating spectrum supportability documents provide acquisition professionals a level of assurance that the required radio frequencies will be available for the operation of the equipment. This, in turn, provides a similar level of assurance that funds will be spent on capabilities that can be employed by Sailors and Marines and will not be wasted on rework.

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15

Unlicensed Radio Frequency Devices

Unlicensed devices are a category of equipment that does not require a license from the Federal Communications Commission or a frequency assignment from the National Telecommunications and Information Administration. They offer great opportunities to system designers and program managers because of their low cost and minimal administrative overhead. But there are important limitations that could affect your decision to use them.

Authorization to Operate

Any device that uses the electromagnetic spectrum to perform its primary function can be described as spectrum dependent. These devices include transmitters, receivers, and, in some applications, a transmitter and receiver combined in the same unit called a transceiver.

Within the United States and its possessions, the two government agencies that authorize the use of the electromagnetic spectrum are the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA).

The FCC is empowered by Congress to provide authorization to the civil population, state and local governments and commercial users. The NTIA, an office within the Department of Commerce, is empowered by the president of the United States to authorize federal government spectrum users such as the FBI, Department of Homeland Security and U.S. military.

Every transmitter must have some form of authorization to operate. Radio and television stations, satellite uplinks, police and fire department radios, airport radars and microwave communications systems all require licensing from the FCC or authorization from the NTIA. However, unlicensed or non-licensed devices do not require an FCC license or NTIA frequency assignment to operate. Unlicensed devices are authorized by special sections of the rules.

Part 15 Rules

The rules and technical specifications that apply to non-federal use of unlicensed devices are in Title 47 of the Code of Federal Regulations Part 15 (47 CFR 15). There are many parts to Title 47, each regulating a different type of radio operation. For example, Part 11 regulates the Emergency Alert System, Part 59 discusses infrastructure sharing, and Part 97 covers the Amateur Radio Service. Part 15 regulates radio frequency devices and contains language specifically regulating the operation of unlicensed devices.

While there are other parts of Title 47 that authorize the operation of devices without a license, Part 15 is the most common, and the term "Part 15" has become synonymous with consumer unlicensed wireless devices.

Once the FCC has certified a device as Part 15-compliant, it may not be modified. Changing anything that affects the electromagnetic transmission of the device will void the unlicensed sta-tus. A change as simple as a different antenna will affect the electromagnetic characteristics and void Part 15 status.

While the FCC regulates non-federal uses of the spectrum, federal transmitters are regulated by the NTIA under the "Manual of Regulations and Procedures for Federal Radio Frequency Management," also known as the "NTIA Manual." Within the NTIA Manual, unlicensed devices are described in Annex K. Annex K mirrors the technical specification of 47 CFR 15 to a great extent, and rules concerning modification of unlicensed equipment apply equally to federal and non-federal users.

Those holding a license or frequency assignment to operate are protected from interference. If licensed devices receive interference from an unlicensed device, and it is reported to the FCC or NTIA, the federal government has the authority to order the user of the offending transmitter to stop transmitting.

Users of unlicensed devices do not have these protections and must accept any interference received, or they must modify operations to eliminate the interference. Protection from interference is the single most important advantage of operating in a licensed portion of the spectrum. You must consider whether or not you can accept the risks of operating without these protections before choosing to use unlicensed devices.

Over the past few decades the growth in consumer electronics has led to an increased number of inexpensive devices built to operate without a license. Unlicensed devices are by far the most common form of transmitter available to the consumer.

From wireless computer networks to garage door openers, electronic car alarms, to walkie-talkies, nearly all of today's electronic consumer devices are unlicensed.

Walk through the electronics department of any store, and you will see dozens of unlicensed wireless devices. The low cost and wide variety of these devices make them attractive for military commercial off-the-shelf solutions. But the benefits of unlicensed devices must always be balanced with the lack of interference protection.

Paragraph 7.8 of the NTIA Manual, "Purchase And Use of Non-Licensed Devices" says: "Federal Government agencies may purchase 'off-the-shelf' non-licensed devices that conform to the applicable edition of Part 15 of the Federal Communication Commission's (FCC) Rules and Regulations (47 CFR 15) without further authority from the Assistant Secretary." Just like our civilian counterparts, federal operators are not required to get a frequency assignment or license before operating a Part 15 device.

The next sentence of paragraph 7.8 says: "Non-licensed devices subject to FCC certification, notification or verification shall bear the appropriate FCC statement of limitations to operations." This means that somewhere on the device there should be a label stating that the device complies with Part 15 of 47 CFR. If the label doesn't say Part 15, but notes some other part of the FCC rules, get clarification from your spectrum manager.

There are other parts of Title 47 that authorize unlicensed use of a device, but they may not be applicable to federal users or they may have specific limitations that conflict with your mission. If it doesn't say Part 15, it probably isn't covered under Annex K, and you might not be authorized to use it.

The next few sentences of paragraph 7.8 contain the deciding factors for whether a Part 15 device is an appropriate solution for your particular requirement. The first part says: "The agency operating a non-licensed device that causes interference to an authorized radio service shall promptly take steps to eliminate the interference. Upon notification by cognizant spectrum management personnel that the device is causing interference, the operator of the non-licensed device shall cease all radiations from the device until the interference is eliminated."

This means that if your operation causes interference to another spectrum dependent device that is properly licensed or authorized, then you must shut down until the situation can be corrected. If there is no way for you to correct the situation you cannot continue to operate. Authorized users are under no obligation to modify their operations.

The last part of the paragraph continues on the same subject: "Agencies operating a purchased non-licensed device have no vested or recognized right to continued use of the device in any part of the radio frequency spectrum. Non-licensed device operations must accept any interference from any federal or non-federal authorized radio system, other non-licensed device, or industrial, scientific and medical equipment."

If you receive interference from users operating in accordance with their license or frequency assignment, and you cannot fix the problem yourself by either moving your equipment, adjusting your antenna, or some other means, you cannot ask the FCC or NTIA for protection. You must accept the interference even if it renders your equipment unusable.

When considering the use of unlicensed devices it is important to weigh the cost and availability with the lack of protection from interference. There are great benefits to Part 15 and other non-licensed devices because they are generally inexpensive and available from a wide variety of sources.

Part 15 devices continue to be a significant enabling technology behind the wireless revolution. Generally, these devices perform as well and, in some cases, even better than their licensed equivalents. However, you must consider all factors before choosing a non-licensed solution.

Know the Rules

If you have a question about using an unlicensed device or to learn more about unlicensed devices please contact your local spectrum manager.

January-March 2006

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=3156

16

Host Nation Coordination: Assuring Spectrum Supportability Outside the United States

Obtaining foreign spectrum support for Marine Corps and Navy operations is referred to as "Host Nation Allocation" (HNA) or "Host Nation Coordination" (HNC). Regardless of the term used, acquiring host nation spectrum supportability from foreign nations is critical to the training and operations of the Department of the Navy (DON), and it is a complex and lengthy process.

Earlier this year, the Joint Staff Director for Command, Control, Communications and Computer Systems (J-6) stated that 51 percent of new Department of Defense (DoD) systems procured in fiscal year 2006 use electromagnetic spectrum. Most DON weapons systems, communications systems, sensor systems, and intelligence systems use electromagnetic spectrum, including radio frequencies, infrared frequencies and more, in some manner.

Obtaining frequency assignments to operate within the

United States and its possessions (US&P) is generally not a challenge because the majority of spectrum-dependent systems procured from U.S. sources conform to U.S. frequency allocation. However, obtaining spectrum supportability for operations outside the US&P is too often problematic.

There are two fundamental factors which must be understood when acquiring host nation spectrum support:

Sovereign Nation Spectrum Rights

The fundamental law of international spectrum is that each and every sovereign nation has the undisputed right to manage and use the electromagnetic spectrum within its borders as it deems appropriate.

Spectrum Allocations

The International Telecommunication Union (ITU) is the international organization within the United Nations that develops international regulations "to ensure rational, equitable, efficient and economical use of the radio-frequency spectrum." The ITU establishes global allocations of electromagnetic spectrum, or radio frequencies, that are intended to support specific types of services: mobile and fixed communications, maritime communications, radar and more, and minimizes harmful radio frequency interference.

ITU spectrum allocations are implemented in most countries throughout the world. Frequency allocations that support specific systems or capabilities within the United States often conflict with frequency allocations in other countries. If these conflicts are not resolved, the result could be radio frequency interference that degrades the capabilities of both host nation and DON systems.

To prevent interference, host nations regularly place restrictions on DON electromagnetic spectrum use within their country. Host nation restrictions, such as terminating radar operations when Navy ships enter host nation waters or limiting frequency-hopping capabilities, can degrade the capabilities of DON equipment.

Although the U.S. equipment certification process is usually not referred to as host nation spectrum supportability, the United States is, in fact, the host nation. Generally, the military services request certification of all spectrum-dependent systems when they are being acquired. The process requires the submission of equipment parameters, including transmitter power, bandwidth, and more, to the National Telecommunications and Information Administration (NTIA), which validates that the equipment operates within U.S. spectrum allocations and is supportable within the US&P. The equipment is then certified and frequency assignments can be obtained for operation within the US&P.

Obtaining host nation spectrum support outside the US&P is similar to the US&P process except that the geographic combatant command (COCOM) is responsible for coordinating host nation spectrum supportability. Again, the military services initiate the process by providing the technical parameters to one or more COCOMs, instead of the NTIA.

The COCOMs operate with the consent of the U.S. State Department and provide the parameters to the host nations. If U.S. equipment conforms to a host nation's spectrum allocations, it generally supports the request. However, sovereign rights and multiple services within a given ITU allocation often prevent naval equipment from receiving host nation coordination, despite the equipment being certified within the

United States.

There is no guaranteed process to ensure all DON systems certified for use in the United States will receive carte blanche spectrum supportability abroad. However, by following these recommendations, the DON can greatly improve the likelihood that spectrum-dependent systems will be supported in host nations.

Organizations procuring spectrum-dependent systems should: Consider spectrum supportability up-front in the acquisition process and consider it as a Key Performance Parameter (KPP); Determine where the equipment will be used and conduct the appropriate research to understand the spectrum allocations of those countries; Solicit the expertise and assistance of the Joint Spectrum Center.

Spectrum access throughout the world is critical to the naval services. Understanding the challenges and processes associated with host nation spectrum support enables organizations involved with the acquisition of spectrum-dependent devices and systems to implement necessary controls that ensure the Marine Corps and Navy remain the most capable military forces in the world.

April-June 2007

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2940

17

Remarkable Professionals Ensure Command and Control of Electromagnetic Spectrum

The Department of the Navy's highly skilled electromagnetic spectrum professionals are more vital to the mission today than ever before.

Without access to the electromagnetic (EM) spectrum, much of the technology that is so integral to our daily lives and military operations could not function, and never before have both peacetime and battlefield access to electromagnetic spectrum been more contested.

High-bandwidth wireless networks in homes, businesses and public spaces and satellite Internet access for ships at sea and troops on the ground have made spectrum an integral part of computer networks. We use remote EM transmitters to control televisions and unlock cars, and cell phones (EM transceivers) to talk, email and text. We rely on radio (EM receiver) and TV for news and entertainment. As inescapable as the EM spectrum is in our personal lives, however, it is essential to military operations.

Unprecedented advancements in wireless technology have resulted in critical shortages of this unseen and finite resource. Without the DON's EM workforce's dedication to ensure spectrum access, the department would be unable to maintain, train and equip combat-ready naval forces capable of winning wars, deterring aggression and maintaining freedom of the seas.

Electromagnetic spectrum, the radio frequency (RF) a system operates on, is a common wireless enabler for many, if not most, new communications-electronics systems. Whether acquired as commercial off-the-shelf products or developed specifically to support naval operations, virtually all spectrum-dependent systems require some action by spectrum professionals before they can be brought into operation.

New spectrum-dependent systems must comply with national and international regulations meant to protect existing users and ensure equitable spectrum access. Ensuring a new system will not interfere with current users is essential to prevent interruptions, degradation or limitations to the effective performance of a system.

Because spectrum is a finite resource, sometimes a frequency band is not available for an emerging technology. To accommodate the entrant, a process called "reallocation" is employed. Spectrum reallocation can be arduous, requiring years of careful national or international negotiations. Spectrum professionals must be vigilant to ensure that agreements reached in negotiations do not negatively affect DON operations. So, in addition to being exceptional technical experts, DON spectrum professionals are skilled negotiators.

One of the spectrum workforce's most fundamental duties is continuous review and evaluation of the DON's radio frequency use to ensure naval forces' ability to operate effectively with minimal impact to the electromagnetic environment. New commercial and consumer uses of spectrum are introduced almost daily, increasing global demand. The resulting changes to national regulations and international treaties demand constant reevaluation and reassessment. The management of increasingly complex systems and their access to the finite EM spectrum in a chaotic environment is just business as usual for the DON's incomparable spectrum management professionals.

The entire DON electromagnetic spectrum workforce of military, civilian and contractor personnel totals fewer than 500 individuals. However, when combined with professionals from the other military departments, federal agencies, the Federal Communications Commission, as well as commercial and private spectrum users, a large workforce of dedicated professionals ensures that the United States EM environment supports cutting-edge wireless technology. Through close coordination and skillful negotiations, these professional spectrum managers are able to ensure consumer wireless technology is able to operate in the same environment along with high-powered commercial and military systems.

Most spectrum managers learn their skills through specialized technical schools while others got their start in the military. A spectrum manager must develop a mastery of general communications policy, as well as the technology and approved architecture, in order to function as a technical authority. Spectrum managers' technical mastery must extend beyond the ability to recommend certain frequencies or frequency bands.

The scope of training includes: regulation of spectrum management; principles of spectrum management administration; mathematics of spectrum management; communication-electronics principles; spectrum planning for line-of-sight, troposcatter and satellite communications systems; navigational aids, radar and non-communications systems; electromagnetic environmental effects; spectrum management in a joint environment and training in service-automated tools.

The DON has long supported professional development. DON spectrum management professionals give back to their community as instructors for the Electromagnetic Spectrum Management Course on Keesler Air Force Base in Biloxi, Miss. Such schools produce a workforce capable of ensuring that the DON's latest acquisitions are employed to their maximum effectiveness with the least possible impact to the electromagnetic spectrum. Continuous curriculum revision at these schools ensures that new spectrum managers graduate with the knowledge and skills necessary to make immediate mission support contributions to the DON. Ongoing professional development helps the electromagnetic spectrum workforce keep pace with the frenetic pace of innovations in spectrum dependent technology.

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18

Strategic Directions in Spectrum Management

The U.S. military's increased dependency on information superiority, proliferation of adversary anti-access technologies, and rising spectrum demand for commercial and military uses are driving change in Department of Defense (DoD) spectrum use.

The Department of Defense Electromagnetic Spectrum (EMS) Strategy - 2013, "A Call to Action" represents the DoD Chief Information Officer's (CIO's) response to this new spectrum reality. The DoD EMS Strategy provides a blueprint for improving how the department adapts to rapidly evolving spectrum environments and for assessing and responding to regulatory and policy changes at home and abroad. The strategy's principles lay the foundation for DoD collaboration with the Administration, other agencies, regulators and industry with regard to national-level planning needed to reduce uncertainty in our future spectrum access.As the starting point for the DoD EMS Strategy, the vision is "Spectrum access when and where needed to achieve mission success.” For naval operations, the implications are particularly meaningful, since freedom of the seas, freedom of navigation and security at sea represent strategic interests for which spectrum is a key enabler.

Secretary of the Navy Ray Mabus recently noted that naval forces offer the unique capability to provide presence, “which really just means being in the right place, not just at the right time, but all the time. Presence helps deter potential conflicts, and it avoids escalating the situation when tensions rise.”

All military spectrum managers know access to radio frequency resources, and control of the electromagnetic environment provides the backdrop that makes this presence possible. The DoD EMS Strategy is the roadmap to ensure that sufficient access to spectrum enables mission success, when and where needed by the warfighter.

DoD Spectrum Strategy

The DoD EMS Strategy, released by the DoD CIO in February, sets three goals: (1) Increase efficiency, flexibility and adaptability; (2) Improve operational agility; and (3) Sharpen responsiveness to spectrum regulatory and policy changes. Some policy improvements require a longer-term evolution. However, as DoD encounters more congested and contested spectrum operating environments, dynamic change has to start now. As a result, the DoD CIO has begun a multi-year effort that will align existing processes and require decisions about the future of key systems and capabilities. The first step is the impending roadmap and action plan for the strategy, with near- and long-term milestones. Some advances can be made quickly, and DoD will continue to improve spectrum efficiency and effectiveness as new systems are fielded over the next five to 20 years.

An increased focus on sharing is already providing a strong foundation as the department implements the EMS Strategy. More and more, DoD must turn to sharing to meet its own growing spectrum requirements. The strategy supports the President's goal to make an additional 500 MHz available for wireless broadband by 2020.

The strategy will enable the department to better navigate the balance between advancing economic security goals by sustaining U.S. wireless innovation leadership, broadband opportunities and national security objectives by ensuring that spectrum is available to meet the military's own growing bandwidth requirements. For the Navy, the challenges surrounding this balance between security and commerce are already well-known, since more than 90 percent of all world trade moves by sea and more than half of global oil shipments cross the ocean.

Against this backdrop of both a globalized economy and evolving security threats, technology innovation is a key factor in carrying out the EMS Strategy, since it will allow the U.S. military to realize a more sustainable future for spectrum-based operations. DoD will acquire efficient, flexible, and adaptable systems with more agile and opportunistic spectrum operations so that commanders in the field can complete their missions.

As a result, military systems will be better prepared to meet the demands of modern warfighting and ensure the technological superiority of our forces. This will require fully leveraging opportunities to use less congested spectrum, adopt commercial services and technologies where suitable and implement spectrum-sharing technologies where feasible.

Military technology innovations continue to contribute to technology innovation and investment in the United States involving spectrum-dependent systems. From the Defense Advanced Research Projects Agency (DARPA) to the Naval Research Lab (NRL), innovation, research and development and a commitment to sharing are all important contributors to broader technology development efforts and the dividends they pay for both U.S. job creation and warfighting capabilities.

Linkages to Navy Efforts

Growing naval spectrum requirements are part of the United States military's increasing spectrum access needs. Navy ship crews must defend against ever more sophisticated threats such as cruise and ballistic missiles. As a result, land-based adaptation of ship-borne radars are part of the North Atlantic Treaty Organization's (NATO) new ballistic missile defenses because they offer the best range, resolution, power and antenna size combination. Signal bandwidth — the frequency range occupied by the transmitted signal — is directly related to how well the radar can resolve target details. This additional information is critical to selecting the best defense against hostile targets. In the 1990s, fleet defense radars used 40 MHz of bandwidth and depended on multiple radars to protect a formation. Today, radars use 400 MHz of bandwidth to detect small, stealthy missile targets. The Navy is already developing the next-generation solid-state radar expected to use 600-800 MHz of spectrum with more power to provide greater detection of multiple incoming targets.

Against this operational backdrop, the EMS Strategy sets a course for how the DoD will address these challenges and opportunities. Many of these efforts are already under way. After the DoD EMS Strategy was released in February, a department-wide integrated project team (IPT) was formed to implement the strategy's objectives. The IPT is led by the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L), the Joint Staff/J6 (supported by the J3) and DoD CIO. The IPT, which is evaluating all facets of DoD's activities in this area, in July will provide a roadmap and action plan to evolve our spectrum access and use. These are "living documents." The strategy, roadmap and action plan will be updated periodically to reflect lessons learned, changing spectrum needs and the evolving electromagnetic spectrum environment (EME).

The EMS Strategy's focus on sharing, technology, partnerships and creative problem-solving are already under way in other policy areas as well. For example, before the strategy was unveiled, DoD proactively advanced national policy objectives for wireless broadband through both sharing and relocation measures by making the frequency band 1755-1780 MHz available for an upcoming Federal Communications Commission (FCC) Advanced Wireless Service-3 (AWS-3) auction through a combination of clearing, sharing and some compression.

The DON has focused on strategic spectrum considerations for several years, including the DON CIO's 2006 "Electromagnetic Spectrum Campaign Plan," which addresses many of the challenges and objectives of the DoD EMS Strategy and the 2007 DON "Strategic Vision for Spectrum." The 2007 Strategic Vision focused on how a proactive, time-phased strategy based on naval warfare requirements would better enable forces to operate any time or any place, with superior capabilities. In 2011, the Secretary of the Navy issued instruction for Electromagnetic Environment Policy and Management, SECNAVINST 2400.2, and in April the DON established a Spectrum Supportability IPT to improve lifecycle continuity and integration of all spectrum supportability processes.

In August 2013, the Navy Marine Corps Spectrum Center and subject matter experts (SMEs) from the DON Spectrum Management (SM) and Electromagnetic Environmental Effects (E3) communities met and recognized the need to integrate and standardize processes to extract common data from current SM/E3 "legacy" business processes. To support this effort, they identified the need to establish a Department of the Navy Spectrum Supportability (SS) IPT and to create a centralized SharePoint site. The SIPR Sharepoint site will be used to collect and share SS/E3 data and host the creation, submission and tracking of Spectrum Supportability Risk Assessment (SSRA) documents as they move through the acquisition and SS business processes.

On April 30, the DON CIO and ASN for Research, Development and Acquisition (RD&A) co-signed a DON memorandum that established the DON Spectrum Supportability IPT to improve lifecycle continuity and integration of all spectrum supportability processes. The guidance in the memorandum applies to the Office of the Secretary of the Navy, the Chief of Naval Operations (CNO), the Commandant of the Marine Corps (CMC) and all Navy and Marine Corps commands, units, installations, organizations and activities.

Partnerships/Way Forward

Successful partnerships — across the military and outside of it — are intrinsic to carrying out the strategy's goals. Going forward, this will include drawing on lessons learned from the U.S. Navy's Strategic Vision for Spectrum, ongoing implementation activities and related efforts to improve naval electromagnetic spectrum agility.

For example, the Information Dominance Roadmap 2013-2028 issued by the Deputy Chief of Naval Operations for Information Dominance, Director of Warfare Integration for Information Dominance (OPNAV N2/N6F) in March 2013, addresses the need for assured electromagnetic spectrum access, including radars. "This will require innovative techniques and adaptive RF solutions that enable sharing of the entire EM Spectrum (including federal and non-federal frequency bands), and leverage gray and white space technology to give the Navy the EM maneuver space it requires to execute war plans under any threat condition," according to the roadmap.

Among the advanced capabilities the roadmap cited in this regard was the ability to field increased numbers of line-of-sight (LOS) communication systems for tactical operations with a common set of shipboard RF apertures and components for communications, EW and navigation radars.

The balancing of federal and non-federal sharing equities is also a center point in proposed rules under consideration now at the FCC that are examining spectrum sharing techniques for advanced wireless broadband technologies in the 3500-3700 MHz band. National regulators are assessing how to allow wireless broadband access and operation in this band through a spectrum access system, a dynamic database or databases that rely on technical and functional requirements to manage access and operations across three tiers. Policymakers are assessing how future rules could protect new commercial systems from co-channel interference from high-powered military in-band shipborne and adjacent band DoD ground-based radar systems.

Through their respective spectrum strategies and related initiatives, including innovative spectrum IPT efforts, the DoD CIO and the Department of the Navy are forward-leaning in assessing the relative operational impacts and opportunities of sharing policies changes, technology advances and new partnerships.

Going forward, these efforts will continue to be refined and improved as part of the goals of the DoD EMS Strategy. The strategy itself is designed to evolve as the spectrum regulatory environment changes, innovative technologies advance, and the threat environment that DoD's spectrum-based capabilities face dynamically shifts. The strategy's goals of increasing efficiency, flexibility and adaptability, improving operational agility and sharpening responses to regulatory changes will provide guideposts to these efforts.

July-September 2014

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=5266

19

Electromagnetic Spectrum Performance Measurement Plan

The Department of the Navy's (DON) Electromagnetic Spectrum Campaign Plan focuses on the importance of the electromagnetic spectrum. "Spectrum," as identified in the campaign plan, enables a multitude of capabilities within the Marine Corps and the Navy, many of which are vital and critical to mission success and safety. The Spectrum Campaign Plan establishes goals and supporting objectives that represent a holistic approach to maintaining Marine Corps and Navy access to spectrum, while ensuring the DON makes efficient and effective use of this critical finite resource.

Five broad goals within the campaign plan address a range of issues including: technology and transformation; federal, national and international spectrum policies; spectrum-related administrative actions; DON and the other services' spectrum publications, directives and policy; and personnel training and spectrum tools. Each objective of the campaign plan is included in a Spectrum Performance Measurement Plan (PMP).

The PMP gauges progress and ensures coordinated efforts by the DON and the other services to achieve the Spectrum Campaign Plan goals. The PMP is a living document that is updated according to guidance and other resources to address new tasks as they arise. Ultimately, the PMP enables a continuous cycle of improvement within the DON. For example, the Department must enhance the accuracy of spectrum data to achieve more efficient and effective use of the spectrum. However, increasing data accuracy for more than 20,000 frequency assignments is a monumental task that can only be accomplished by balancing available resources with DON objectives.

The following provides a sampling of tasks from the PMP and a brief explanation of their importance to the DON.

Task 1.1

Matrix DoD RFID policy with DON, USMC and USN policy

The use of radio frequency identification within the Navy and Marine Corps continues to increase; RFID is now used for various purposes within the DON. In addition to the capabilities RFID provides naval logistics, RFID has potential benefits to nearly all occupational fields. As such, DON policy must not only support RFID capabilities, but must also ensure operations are implemented to minimize radio frequency interference.

Task 1.2.

Conduct the Secretary of the Navy Lean Six Sigma project: Spectrum supportability for equipment flowing to theater.

This initiative ensures rapidly procured spectrum-dependent equipment is fielded with sufficient technical information to avoid unknown or detrimental effects to existing equipment operating within the U.S. Central Command's area of responsibility which includes 2525 nations, ranging from Egypt in the west to Pakistan in the east, from Kazakhstan in the north to Kenya and the Horn of Africa in the south. This project is planned for completion in February 2008.

To increase the efficient use of the spectrum, the National Telecommunications and Information Administration (NTIA) has mandated that all federal land mobile radio (LMR) systems within the United States and its possessions, including those used by the Marine Corps and Navy, must transition from wideband operations (2525 kilohertz) to narrowband (12.5 kHz) before 2008. The naval services have made significant progress; however, like other federal organizations, the Marine Corps and Navy will not be fully compliant by the end of the year. This task will ensure that waivers for all naval wideband (noncompliant) LMR systems are submitted. It will ultimately ensure continued, uninterrupted operation of DON LMR systems during the Department's narrowband migration.

Task 2.1.

Identify all DoD, federal, national and international policy and guidance that address spectrum supportability.

The DON acquisition community has a daunting task to procure spectrum-dependent equipment that enables naval capabilities throughout the world. In doing so, they must conform to policies that mandate a plethora of standards and procedures. This task is intended to identify all spectrum policy and guidance. It will ultimately enable the strategic alignment of spectrum-related requirements levied on the acquisition community to ensure those requirements are realistic and attainable.

Task 2.2.

Develop a comprehensive matrix of all World Radiocommunication Conference 2007 (WRC-07) and international bilateral meetings for 2007.

The Marine Corps and Navy have global responsibilities. DON advocacy within international forums influences the development of international spectrum policy that protects and benefits naval capabilities.

Task 2.3.

Develop a comprehensive matrix of DON assessments, engineering analyses, position papers, advisories and updates in support of WRC-07.

The DON CIO advocates the interests of the DON and ensures awareness of WRC-07 preparations and potential outcomes. The DON has originated and distributed a number of documents, including assessments and memoranda that address issues of significance from WRC-07. These documents have been critical to the development of U.S. positions that protect and enhance global Marine Corps and Navy capabilities.

Task 2.4.

Develop a comprehensive matrix of all agreements regarding spectrum use between the DoD, federal government, Mexico and Canada.

Marine Corps and Navy training within the continental United States routinely occurs along the Mexican and Canadian borders. Similar to the DON's participation in multinational spectrum forums, the advocacy of the DON position in DoD and federal bilateral spectrum negotiations with Mexico and Canada is essential.

Providing global spectrum access to deployed naval forces for training or operations is an unending, immense challenge that requires collaborated and coordinated efforts throughout the DON. Completion of all tasks in the DON's Electromagnetic Spectrum Performance Measurement Plan may not ensure worldwide spectrum access for the Marine Corps and the Navy, but it will ensure that Department, Marine Corps and Navy spectrum personnel will work together in the best spectrum interests of the naval services.

October-December 2007

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2871

II

Full Spectrum

Policy and Rules
Sharing and Reallocation
Changing the World
The Future

20

A Spectrum Management Perspective on Cell Phone Signal Boosters

Recent changes in Federal Communications Commission (FCC) regulations governing signal boosters enable the sale of certain types of these boosters within the United States. Signal boosters are devices that can improve cell phone coverage in areas where they do not get a good signal. The FCC's new rules create two classes of signal boosters — consumer and industrial — each with distinct regulatory requirements. The Department of the Navy can benefit from these changes provided spectrum-dependent programs follow DON spectrum guidance when using these boosters.

Federal use of the radio frequency spectrum within the United States and its possessions (US&P) is authorized by the Assistant Secretary of Commerce for Communications and Information and regulated by the Department of Commerce National Telecommunications and Information Administration (NTIA). Federal agency spectrum regulations are contained in the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management).

In response to the FCC changes, the NTIA updated Section 7.23 of the NTIA Manual, “Federal Government Agencies as End Users of FCC Licensed Commercial Services,” to allow federal agency use of both industrial and consumer signal boosters. However, federal operation of end user radio devices is under the control of the FCC licensee, and federal use must be in accordance with FCC rules governing the specified service.

Section 7.23 of the NTIA Manual states: “Federal Government entities may, without further authority from the Assistant Secretary of Commerce for Communications and Information, operate radio devices as end users in commercial FCC-licensed systems in the services listed below. Operation of end user radio devices is under the control of the FCC licensee, and Federal use must be in accordance with FCC rules governing the specified service. This section does not relieve Federal users from any other policy requirements and it is the responsibility of the Federal user to determine if its operations are eligible to operate under the FCC license or under the FCC rules.”

Navy and Marine Corps organizations considering using signal boosters are reminded that FCC regulations only apply within the US&P. Operations outside the US&P are regulated by host-nation agreements that may not permit their use. Also, using signal boosters aboard naval ships, aircrafts and installations requires special consideration for electromagnetic environmental effects.

Other requirements, such as the completion of a spectrum supportability risk assessment and registering technical parameters in the Equipment Location-Certification Information Database may also apply.

The electromagnetic spectrum is a dynamic environment.

Before purchasing any radio frequency spectrum-dependent device, DON personnel are reminded to consult with local spectrum management or the Navy Marine Corps Spectrum Center.

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21

Rules create sharing between federal and non-federal radio systems

The National Telecommunications and Information Administration (NTIA) Interdepartment Radio Advisory Committee (IRAC) recently approved an addition to the Manual of Regulations and Procedures for Federal Radio Frequency Management.

The new paragraph, 8.2.47, enables federal and non-federal agencies to share radio systems. Navy and Marine Corps first responders may have an opportunity to dramatically expand their geographic coverage without the prohibitive cost of building additional infrastructure. This change in governance charts a new course away from federal and non-federal agencies jealously guarding their allotted spectrum. Before this change, sharing among federal and non-federal radio systems was extremely difficult and as a result, rare.

The electromagnetic spectrum, which these radio systems utilize, is a sovereign resource of every nation to manage as they see fit. The United States manages spectrum usage under two sets of rules, one for federal government agencies, such as the departments of the Navy, Justice and Homeland Security, and one for non-federal agencies, including state, local and tribal police; fire and ambulance services; business radio; broadcast television and radio; and more.

United States Code further separates portions of the radio spectrum into frequency bands for exclusive use among federal users, and other bands for exclusive use among non-federal users. Even though there may be no operational restriction to sharing frequency resources, these regulatory limitations made it difficult, if not impossible, to share radio systems between federal and non-federal users.

The Department of the Navy Chief Information Officer (DON CIO) will lead a push to expand Navy and Marine Corps systems to take full advantage of this new opportunity. All Land Mobile Radio System (LMRS) operators are encouraged to evaluate their current service area and determine if their system coverage and capabilities may be expanded under the new rules. Many systems may be able to expand their service area with minimal or no new equipment. Navy and Marine Corps land mobile radios may already be capable of taking advantage of non-federal frequency bands.

Sharing among federal and non-federal radio systems involves a three-step process. First, the federal and non-federal users must agree to share. This agreement is then coordinated with the IRAC to ensure it adequately addresses the needs of the government, including the return of federal frequencies if all federal users withdraw from the system or if the federal frequencies are no longer available for non-federal use.
Second, the federal user must submit technical information about the non-federal system to the IRAC to certify that it is in compliance with other rules governing federal radio systems.

And lastly, the federal user requests the federal equivalent to a radio frequency license in the non-federal frequency band.

The exact process and procedures, in paragraph 8.2.47 of the NTIA Manual, are reprinted in the text box below. However, as of press time, the NTIA Web site had not been updated with the newly approved paragraph.

State, local and tribal radio system operators are also encouraged to explore how they will share in this new opportunity.

Sharing spectrum is an alternative to spectrum reallocation. Over past decades various actions have been taken to reallocate spectrum among federal and non-federal users. The process of migrating operations out of one frequency band and into another requires considerable time and resources.

Spectrum is critical to our nation's economy and security. Sharing empowers all users to efficiently and effectively execute their careful stewardship over this finite resource.

July-September 2009

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2649

22

Cross Banding: Enabling Communications Interoperability Among First Responders

Interoperable communications between federal first responders and non-federal first responders is a vital capability that must be pursued by the Department of the Navy (DON) because Navy and Marine Corps installations have a close, cooperative relationship with adjacent federal, state and local first responders.

Ensuring interoperable communications for police, fire, emergency medical services, and other first responder services, is a challenging endeavor that can be achieved and ultimately betters the posture and capabilities of the DON.

Interoperable communications for federal, state and local first responders provide significant benefits in crisis management operations where immediate communications can save lives and prevent the loss of property. But ensuring interoperable communications is a complex process that involves a number of factors, including communications control and coordination of radio frequencies.

Coordination of federal and non-federal radio frequencies used for first responders is not exceedingly difficult; however, there can be challenges emplacing necessary agreements and determining technological configurations that are essential to interoperability.

Preparation is the key to successful interoperability. Interoperability plans and agreements should be preprogrammed, and the spectrum (radio frequencies) required to support these operations should be identified and allocated before an incident requiring interoperability is encountered.

Ad hoc plans and solutions are more likely to result in communication shortfalls than solutions that were pre-planned and ready for implementation.

The first step in attaining interoperability is understanding how spectrum is allocated and may be shared and used within first responder agencies. U.S. spectrum governance was purposefully created to protect federal and non-federal spectrum equities; however, the role of the federal agency first responder in domestic emergencies has increased dramatically over the past few decades.

The U.S. radio frequency spectrum is allocated among federal and non-federal services, and use is governed by similar yet different organizations. The use of federal radio frequencies is governed by the National Telecommunications and Information Administration, while non-federal spectrum use is governed by the Federal Communications Commission.

The NTIA and FCC both recognize and support the use of spectrum for interoperable communications between federal and non-federal first responders.

Federal radio frequency users include the departments of the Army, Navy and Air Force, U.S. Coast Guard, and the departments of Justice and the Interior. Sharing federal radio frequencies between federal first responders requires only agency to agency coordination. Agencies are not required to obtain frequency assignments to share the system provided that there is a federal agency that has obtained a federal radio frequency assignment, and that agency consents to other federal agency use.

Federal agencies can obtain frequency assignments in frequency bands allocated exclusively for non-federal use; however, this action requires NTIA and FCC approval and generally requires significant coordination time to ensure that the NTIA and the FCC can support a given frequency assignment. Information on establishing this type of interoperability can be found in paragraph 8.2.48 of NTIA's Manual of Regulations and Procedures for Federal Radio Frequency Management. Resulting frequency assignments are granted with the provision that no harmful interference will be caused to the service rendered by non-federal stations, present or future.

State, local and tribal governments, as well as commercial and private radio users, are examples of non-federal users. Similar to federal agency use of non-federal frequency assignments, non-federal frequency assignments may be authorized in a frequency band solely allocated for federal use. And, similar to federal organizations obtaining non-federal frequency assignments, the assignments require FCC and NTIA coordination. Resulting assignments are provisioned so that no harmful interference will be caused to the service rendered by federal stations, present or future.

Akin to the coordination time for federal frequency assignments in non-federal frequency allocations, non-federal assignments in federal frequency allocations will often require considerable coordination and time.

A common misconception concerning interoperable communications is that all parties must operate on the same frequency. But there are radio systems and equipment that can "cross band" a frequency from one frequency band to a frequency from a different band. Cross banding is transparent to users. Equipment of this type provides many advantages and eliminates the associated challenges of coordinating, acquiring and maintaining "out of band" frequency assignments.

Cross band capabilities allow federal users to operate on frequencies managed by the NTIA, and non-federal users to operate on frequencies managed by the FCC while providing interoperable communications without the use of a single frequency. As such, cross band capabilities minimize the complexity of frequency coordination and use while providing fully interoperable communications.

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23

Electromagnetic Spectrum: Battleground in Warfare Dominance

For countless ages, military forces have met on the battlefield. The first battles were likely fought as skirmishes by small land forces and later by nation-states in land and sea conflicts. Inventions and innovations from the 20th and 21st centuries expanded warfare from the land and sea into air, space and cyberspace "domains."

Electromagnetic spectrum, which came of age in the 20th century, might also be considered a separate battle-space, with similarities — and differences — to the better known warfighting domains.

Ancient disputes were not only fought on land, but warriors also used weapons refined from the land. For example, stone spearheads and metal swords were produced from local resources. Today's electromagnetic spectrum battle-space is very similar. Weapons that are being designed and developed to fight in the electromagnetic battle-space use electromagnetic spectrum as a weapon.

Just as land, sea, air, space and cyberspace operations are separate but inseparable, electromagnetic operations are separate but inseparable from these war-fighting domains. Modern warfare would be unmanageable without access to electromagnetic spectrum. The control and superiority of the electromagnetic spectrum environment is unquestionably a prerequisite to ensure effective operations within all war-fighting domains.

Electromagnetic spectrum is a physical domain consisting of all electromagnetic energy, both natural and man-made. Mobile phones, Wi-Fi connections, microwave ovens, satellite television and cable services are examples of our daily spectrum usage. The electromagnetic spectrum environment exists even though we may not be aware of its presence.

The frequency ranges of a tactical radio or a mobile phone are definable even when they are not supporting a transmission (i.e., not being used). Most military use of this environment is more sophisticated than the normal applications in the commercial domain. Radio and data communications, active and passive sensing, selective jamming and employing directed energy devices are a few illustrations of electromagnetic spectrum supporting critical operations. Such systems operate within one or more of the commonly known battle-spaces, but their presence in the electromagnetic spectrum means they also represent a segment of the very battle-space in which they fight. Since a majority of these systems use electromagnetic spectrum to operate, electromagnetic spectrum is a vital resource.

Electromagnetic spectrum has existed since the beginning of the universe. Within moments of the big bang, it was electromagnetic energy that condensed into matter as defined by E=mc2. Our universe continues to become more dependent upon electromagnetic energy. The evolution to control unmanned aircraft, unmanned vehicles, and even unmanned maritime systems is a significant and unplanned burden for spectrum.

While human beings are becoming better stewards of our natural resources, like land, air and water, there is recognition of the need to enhance our stewardship of the electromagnetic environment in better managing interference, encroachment and other electromagnetic environmental effects.

While the electromagnetic spectrum shares many commonalities with the land, air, space and cyberspace domains, it is unique in that the electromagnetic spectrum is simultaneously a resource with which we communicate and conduct operations. This is an environment that requires our protection and projection to achieve superiority. Electromagnetic spectrum is definitely a weapon, and it has also become a battlefield upon which we will continue to fight.

Earlier militaries considered land, air and sea as the traditional battle-space. Past battles have demonstrated the synergy of sea power and air dominance to support success in land operations. The recent focus on space and cyberspace as evolving battle-spaces force an examination of electromagnetic spectrum as a key battleground in warfare dominance.

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24

Streamlining Real Estate Processes for Commercial Wireless Broadband Deployment

Smartphones changed everything. In fact, it is hard to contemplate a time before the smartphone. They are the first thing many of us grab in the morning when a wake-up alarm goes off, and the last thing we grab as we walk out the door of our offices. They are also the first thing Sailors and Marines grab when their ships come ashore. The loss of a wallet is unfortunate; the loss of a smartphone is catastrophic!

Wireless broadband technology has become embedded in our culture and the smartphone is essential for many us to obtain the information we need and remain in contact with our families and friends.

The first commercial cell phone network was created in 1983, but cell phone usage did not expand until the 1990s. The introduction of the smartphone in 2007 accelerated the demand for commercial wireless broadband technology. Access to commercial wireless broadband is dependent on the installation of infrastructure equipment in appropriate locations to provide "coverage" to service areas. The installation of this equipment on Department of the Navy properties triggers real estate considerations, which forced a change in DON real estate procedures.

Prior to the proliferation of cell phone usage, communications equipment installed on DON installations was primarily owned and operated by the Department of the Navy to support the mission, by local municipalities for emergency services, or by communications companies that connected a base to local and long distance telephone systems (i.e., back-haul services). Real estate considerations in those situations were fairly simple. The communications equipment being supported was for a public benefit, which made it fairly simple to issue an easement, which is the right to use a property for a specific purpose without owning fee title to it. Also, the number of requests for real estate agreements for telecommunication purposes was relatively low, thus making it easy to manage the workflow.

The tide was turning, though, in the mid-1990s. The Telecommunications Act of 1996 was passed, seeking to foster competition in all telecommunications and broadcast markets. In response, the Naval Facilities Engineering Command (NAVFACENGCOM), the Navy's real estate executive agent, published its 1996 interim real estate guidance for telecommunications. This guidance called for the use of leases, rather than easements, for cell phone companies installing equipment on DON land. The rationale for this change was that cell phone companies provided a service for commercial gain and were fundamentally different than other communications entities providing services for a public benefit. As such, the increased time involved in lease execution was not seen as an issue.

That all changed with smartphones. Suddenly many more requests started coming in from telecommunications companies for access to DON installations to install wireless broadband equipment. The changing nature of cellular service caused confusion within the real estate community. The line between public benefit and commercial venture became blurred, and it was unclear if cell phone companies were indeed fundamentally different than other forms of telecommunications.

In 2015, the Federal Communications Commission (FCC) addressed that issue when it decided to treat the internet, and by extension wireless broadband, as a utility that is no different than a water or electrical distribution company. This is an important distinction in the real estate community. Standing real estate authorities in Title 10 and Title 47 of the U.S. Code allow the DON to issue easements for telecommunications towers and equipment when not in conflict with public benefit. An easement can be issued for a site without competition, and all applicants are accommodated up to the point where a location can no longer accommodate any more applicants.

Prior to this distinction, the DON relied on the standing Title 10 leasing authority to issue leases, which states that the granting of a lease to a commercial entity must be competed. The competition process can be lengthy, potentially up to 180 days. That is a long time for a company seeking to install additional equipment to prevent its network from failing in the face of increased demand. Also, unlike easements, leases convey an exclusive use over the real estate, thus potentially shutting other companies out. This FCC distinction made it clear that easements were, in general, the appropriate real estate agreement with telecommunications providers.

Easements can be tailored to contain many of the elements of leases, including annual payments by a commercial entity vice a one-time payment and removal of equipment at the end of the easement period. Additionally, easements can be issued in a relatively short period of time. More important, easements can be issued for relatively long periods of time and can include options to extend without seeking Secretary of the Navy approval. In short, easements normalize the real estate process for wireless broadband companies, thus making routine something that previously was not.

Prior to the FCC decision, the President signed an Executive Order in 2012 directing Federal agencies to develop streamlined policies supporting broadband deployment. Coupled with the subsequent FCC clarification, the Office of the Assistant Secretary of the Navy for Energy, Installations and Environment (OASN EI&E) and the DON Chief Information Officer (DON CIO) led a working group made up of DON installation spectrum, public works, and real estate experts in an efficiency initiative with a goal of achieving significant time reduction. The resulting process is the focus of a memorandum issued by the Deputy Under Secretary of the Navy (Management) on June 30, 2016 concerning deployment of wireless broadband on DON installations, including real estate agreements for cell phone companies.

Though a cliché, it is true that change is hard. To ensure unforeseen issues specific to individual installations are not ignored, and to encourage the real estate community to embrace the required changes, this new policy requires installations to report any instance where it takes longer than one year to issue a real estate agreement. The policy also encourages spectrum, facilities, environmental and real estate planning processes to be conducted in parallel vice sequentially. The policy's goal is to normalize all the processes, including real estate, to the point where an answer to a request can be given within a few months vice years. There have been instances in which it took up to five years to complete a broadband deployment process.

At their introduction, I doubt many people were thinking about the fundamental changes the smartphone would bring to information sharing and personal communications. However, given the continued growth of smartphone technology and usage, it is safe to assume that such change will lead to increased requests by cell phone companies to access our installations to enhance wireless coverage. The Streamlined Process for Commercial Broadband Deployment policy is designed to speed the processing of such requests.

More important, this policy is designed to improve wireless broadband access by DON personnel and their families. Deployment of wireless broadband on our installations is a quality of life and force enabler issue that we must embrace. The new streamlined broadband coordination process policy eases that deployment.

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25

Navy and Marine Corps: Good Neighbors in the Frequency Spectrum Community

Encroachment issues commonly occur between neighbors when homeowners add a new feature to their home that extends onto another landowner's property, such as the addition of a new patio or a landscaping feature.

When structural encroachment disputes occur over clearly defined property lines, legal remedies might include easements or a legal order to remove the disputed structure. However, not all encroachment issues are as easy to resolve.

If your neighbor built a second story on his house that blocks your cherished scenic view, or built a new garage close to your property line that causes snow to drift across your driveway, this may, or may not, be considered encroachment under the law. Unfortunately, the impact to you is the same: your neighbor has acted without considering how the change will affect your quality of life.

Imagine for a moment if your neighbor's new second floor blocked the signal for your satellite TV reception, or if every time he used his remote control security system, your car door unlocked. Under the law, this may, or may not, be encroachment into your property. These types of conflicts do occur; they are known as frequency spectrum encroachment, and they have become a very real concern for the Navy. In this article we will discuss a few things that the Department of the Navy is doing to resolve frequency spectrum encroachment.

In his 2010 Presidential Memorandum: "Unleashing the Wireless Broadband Revolution," President Obama wrote, "Innovative new mobile technologies hold the promise for a virtuous cycle — millions of consumers gain faster access to more services at less cost, spurring innovation, and then a new round of consumers benefit from new services."

While consumers are enjoying a rapid evolution in new wireless technologies, many of these technologies must compete with the Navy's usage of the electromagnetic spectrum for a wide range of applications including communications and radar technologies. Unlike roadways, power lines, water pipes or other physical infrastructure, which can be expanded to meet increasing demand, the frequency spectrum is a finite resource.

Increased demand requires complex coordination and management as spectrum encroachment may limit the Navy's ability to use test and training ranges, special use airspace, such as military operations areas, and other operating areas used to conduct critical training and testing to assure our warfighters are the best they can be.

Frequency spectrum encroachment can not only create disruption between wireless systems, but can also threaten the close relationships between the Navy and its neighbors if Navy operations create interference in the surrounding communities. The Navy and Marine Corps strive to be excellent neighbors; therefore it is vital that we address these issues quickly and in a manner that is mutually beneficial wherever feasible. Frequency encroachment challenges are not limited to civilian communities, they can also occur between government entities, for example, when military technology sold to civil law enforcement results in encroachment if spectrum supportability is not closely managed.

The President addressed this in his 2014 Presidential Memorandum: "Expanding America's Leadership in Wireless Innovation," when he wrote, "We must continue to make additional spectrum available as promptly as possible for the benefit of consumers and businesses. At the same time, we must ensure that Federal, State, local, tribal, and territorial governments are able to maintain mission critical capabilities that depend on spectrum today, as well as effectively and efficiently meet future requirements."

In our personal lives, an inconsiderate neighbor may build monstrosities with little regard for how they may affect their neighbor's property values or quality of life. A considerate neighbor will discuss his plans. In some neighborhoods, local covenants mandate concurrence between neighbors before new construction permits are issued. The same is true among spectrum users. In some circumstances, emerging technologies barge into the spectrum with little consideration of the impact on their spectrum neighbors. Fortunately, most members of the spectrum community work hard to be good neighbors. Depending on the situation, there are voluntary and mandatory forums where spectrum neighbors can get together to discuss their plans and avoid or minimize encroachment.

The newest challenge to spectrum encroachment, much like your neighbor's second story blocking your satellite TV signal, is associated with non-spectrum related structures. These structures are not intended to transmit, and therefore are not required to be certified into the local electromagnetic environment. However, these structures may impact their spectrum neighbors. Just like your considerate neighbors didn't intentionally block your TV signal, new construction is not designed to intentionally block radio frequencies. Had you known your neighbors were planning construction, you could have planned to move your satellite dish.

In the case of a blocked view, very good neighbors might even alter their plans slightly to maintain neighborhood harmony. Recently, several forums have been developed among Navy and Marine Corps spectrum users and their local spectrum or non-spectrum neighbors to offer a venue for addressing encroachment issues. Most are voluntary, but a few, like the DoD Siting Clearinghouse, have been mandated by Congress.

As new wireless technologies continue to explode in popularity, the coming years will be a critical time to address spectrum encroachment issues. We must be vigilant in protecting Navy and Marine Corps systems from encroachment while simultaneously striving to be good neighbors and preserving our relationships with local communities and government agencies.

April-June 2015

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26

Radio Frequency Congestion

We are all familiar with overcrowding and traffic congestion. Most people in the United States experience long work commutes, jammed shopping malls, as well as long lines at restaurants, train stations and other locations where people frequently congregate.

However, congestion in these occurrences usually has peaks and valleys, and many times, people can arrange their schedules to avoid peak times. Some people living in rural areas have never experienced overcrowding.

The use and congestion of radio frequencies (RF) parallels that of roads, shopping malls and restaurants. While radio frequencies may be congested in some geographical areas, many geographical areas of the world and of the United States rarely, if ever, experience frequency congestion.

Natural resources such as oil, coal and precious metals are limited or finite and are in high demand; similarly, radio frequencies from the electromagnetic spectrum are also in high demand.

However, radio frequencies have one significant difference when compared to those other resources. Radio frequencies are instantaneously recyclable; the use of a frequency to communicate between radio devices does not deteriorate or consume that frequency.

Because of this radio frequency characteristic, radio frequencies can be shared and reused worldwide. Consequently, due to the ability to reuse and renew radio frequencies, congestion is generally limited to geographical areas where population density is high. This means that the preponderance of RF congestion is experienced at specific, geographical locations and predictable times that directly correlate to the typical use of wireless capabilities and devices.

For example, radio frequency use surges in the morning as people commute to work, during the commute home and into the early evening.

But not all spectrum usage is predictable. For the Navy and Marine Corps, unanticipated congestion within certain frequency bands is increasing. The requirement for 24/7 operations places unique demands on the use of radio frequencies, and new requirements for sensor and unmanned aerial system capabilities now strain available RF resources.

This RF congestion has reached the point where some strategic and tactical operations, such as use of unmanned aerial systems, must be scheduled to avoid frequency fratricide with other UAVs and other RF equipment operating within the same geographical area.

RF congestion is not going to diminish anytime soon. The use of RF-enabled capabilities continues to increase. However, there are actions that can be taken by warfighters and acquisition officials to minimize RF congestion.

Warfighters should always make their RF requirements known to responsible spectrum planning and operations personnel and always use only radio frequencies that have been provided by such personnel.

Acquisition officials should always consider radio frequency use from the warfighter's perspective when developing or acquiring systems and equipment.

Spectrum is a resource in high demand throughout the world. Use of the spectrum fuels the economy and enables a plethora of Navy and Marine Corps capabilities. While radio frequency congestion is a reality for Sailors and Marines, employing spectrum-dependent equipment in a congested environment can be managed if warfighters and acquisition officials recognize the risks and challenges associated with its use.

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https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2616

27

DON Manages Increasing Spectrum Encroachment

Naval installations have long been good neighbors with their surrounding communities. In fact, in many cases, Navy and Marine Corps bases, posts and training ranges limit some operations to preserve friendly relationships.

When many military installations were initially built, they were literally in the middle of nowhere. Cheap land and wide open spaces meant that Sailors and Marines could train in relative seclusion. But this isolation could not last forever in a rapidly growing nation. And as people moved closer to military installations and airfields, what were once non-issues, such as aircraft noise, became points of contention within communities. Likewise, amphibious landing exercises on once secluded beaches became disruptive to tourism because modern highways made remote locations more easily accessible.

As a result, many restrictions were enacted within the past two to three decades in consideration of the growing populations living near military installations. Operational restrictions curtail aircraft and machinery noise, protect wildlife and limit carbon emissions into the atmosphere.

The continued encroachment on Navy and Marine Corps real estate even affects the type of training and operations that can be conducted on installations. Many restrictions are permanent, but some are limited to specific times of the day, month or year.

The Department of the Navy's electromagnetic spectrum, or radio frequency, use is similarly affected by encroachment. During the past decades naval spectrum use grew proportionally to public and commercial use. For most of the 20th century, the Navy and Marine Corps had ample spectrum to support communications, radar and other spectrum-enabled capabilities. Spectrum use, though always regulated, was relatively unimpeded.

But near the end of the 20th century, the emergence of a plethora of wireless capabilities, made possible by the use of radio frequencies, began to affect the amount of spectrum available to naval forces. While public and commercial spectrum use, as well as federal government use, increased dramatically in recent decades, so too has the military's reliance on spectrum.

To help ensure harmony with public and commercial spectrum requirements, restrictions limiting naval spectrum use, such as time, location, altitude and propagation, are often placed on DON installations just as training and operational restrictions are imposed.

Some spectrum restrictions intend to prevent radio frequency interference to public and commercial spectrum use; while others are self-imposed to prevent interference between Navy, Marine Corps, Army and Air Force equipment.

As spectrum use increases, spectrum encroachment will continue to challenge the Navy and Marine Corps when conducting realistic training and day-to-day operations. The DON maintains a unique and diverse cadre of spectrum professionals who understand the department's spectrum requirements, ensure they are met and comply with international, federal, Department of Defense and DON regulations.

The department's globally dispersed spectrum team of civilian and military personnel are located at installations, training ranges, major commands and operational organizations throughout the nation and the world. This team coordinates and negotiates the department's usage of spectrum with host nation governments and non-government entities.

Access to and use of spectrum continues to be vital to the nation's naval services. The DON, in its continuing efforts to ensure spectrum is available, will also continue to ensure that its use is in concert with commercial and public spectrum use — as a good neighbor should.

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https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2449

28

Assessing the True Value of Spectrum

There is little argument that the electromagnetic spectrum is valuable: A few megahertz can sell for billions of dollars at auction. However, the true value of spectrum is in how it is used. For example, we are all familiar with WiFi or wireless broadband. Our cellular phones and other connected devices have become critical to our modern lifestyles. Most would agree that the value of this spectrum usage is extremely high. These are just a few of the many devices that depend on spectrum to operate.

Additional examples include radar that is used to track aircraft and the weather. Telemetry systems relay equipment test and experimental data. And Land Mobile Radio provides our law enforcement and first responders with critical communications capabilities. These devices can be called "active" systems, other systems are "passive" in nature, such as passive receivers that listen to spectrum but do not transmit, providing value without introducing additional energy into the electromagnetic environment.

Some passive systems are used for scientific research such as for an environmental study or radio astronomy. The value of the electromagnetic spectrum as used by these passive systems is incalculable. Such spectrum usage enables monitoring solar weather, which could impact the global electric grid. These passive spectrum systems also advance general knowledge by expanding our understanding of our place in the universe. Passive systems often use exceptionally sensitive receivers, which are very difficult to protect from electromagnetic interference and are uniquely vulnerable to the electromagnetic energy transmitted by other users.

Electromagnetic spectrum has long been critical to our nation's security and economy. The Department of the Navy Chief Information Officer addressed this issue in a video "Electromagnetic Spectrum, Critical to our Nation's Security".

As technological advancements lead to greater use of electromagnetic spectrum, its value to both our national defense and our nation's economy continues to increase. The amount of spectrum available is limited only by users' abilities to coexist and share access with other spectrum users. Fortunately, continual advances in technology create increasing opportunities for sharing.

Electromagnetic spectrum management policies have evolved during the course of the last 100 years through a series of economic and political events. Federal spectrum regulators are responsible for protecting public (government/military) interests while offering opportunities for profit to the private sector (wireless providers). Maintaining the proper balance between private spectrum ownership and public spectrum access is a continuous challenge.

This challenge involves the responsibility of federal spectrum users to protect mission requirements and operate spectrum-dependent systems in a specific frequency band while also considering the potential to supplement their federal appropriations with money received from spectrum auctions. Operational concerns, limited resources, and perceived spectrum inefficiencies are all issues agencies address as they weigh the pros and cons of selling spectrum.

Finding balance between private ownership and public access has never been easy. Determining how a specific band of electromagnetic spectrum provides the greatest value must include consideration for the greater public interest. The benefits of public spectrum are critical to electromagnetic spectrum policy debate. The public good of electromagnetic spectrum has long been recognized. The opportunity to provide private spectrum ownership has only recently been explored in the United States. Given the lure of auction returns for private access, we must assure that the interests of public use requirements are receiving appropriate attention.

Future spectrum users will continue to strive for more efficient spectrum-dependent systems. Greater effort will be made to preserve and protect the electromagnetic environment. And spectrum auctions will be based on spectrum utility. Policymakers will continue to learn from the lessons of the past and proceed with caution to assure they are safeguarding future public spectrum interests and the electromagnetic spectrum itself.

The future of spectrum involves both sharing this valuable resource and protecting the fragile environment. The true value of spectrum is often many times more that the price it will bring at auction.

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29

The Spectrum Sharing and Reallocation Dilemma

The electromagnetic spectrum is a unique resource. While in some ways it is similar to other resources, like oil or water, in other ways, it is very different. The electromagnetic spectrum is typically defined as the set of all non-ionizing radiation electromagnetic frequencies.

The electromagnetic spectrum we are most familiar with is a finite collection of frequencies between about 3,000 cycles per second (kilohertz), or 3 kHz, and 300 billion cycles per second (gigahertz), or 300 GHz. These frequencies are used in radio frequency systems.

The electromagnetic spectrum is unlike any other resource we use. Not only is electromagnetic spectrum finite, it is also instantaneously renewable. The moment one system stops using a set of frequencies — another system can begin using it. As a finite resource, the electromagnetic spectrum is in short supply, but its instantaneously renewable properties provide a near perfect resource for sharing.

The electromagnetic spectrum is managed by allocating particular sets of frequencies, known as bands, to different uses. Some bands may be used for satellite communications while others may be used for radio astronomy. Without allocating different uses to different parts of the spectrum, one system may interfere with the operation of another.

Due to increased spectrum use, it has become difficult to obtain and use many frequency bands in the United States, as well as in many foreign countries. As such, increased electromagnetic spectrum sharing requirements are imposed on spectrum users worldwide. Sharing spectrum can be accomplished in several ways. Technological capabilities, policies and cooperation agreements among users are some of the broad sharing techniques implemented today to maximize the use of the electromagnetic spectrum.

While sharing spectrum has some challenges, it is often possible for some spectrum-dependent systems and equipment to share without causing interference with other systems using the same spectrum. The most common example of sharing is geographical separation, which has been used for nearly a century.

Use of early television frequencies could be shared because television stations were located hundreds of miles apart. Technology can also provide spectrum sharing opportunities. Equipment that transmits radio frequencies at very low power levels may create only a slight rise in background noise. This characteristic provides the ability to reuse radio frequencies efficiently over much shorter distances.

There are also more sophisticated sharing scenarios, including the use of information technology databases that provide detailed information about spectrum-dependent systems and equipment, and their geographical location and transmission media data, as well as what types of signals may cause interference.

Advanced technologies can also “sense” the presence of a radio frequency signal and wait to transmit until other equipment or systems cease use. In many cases, sharing radio frequencies can be accomplished with minimal encroachment for most spectrum users.

However, whether as a result of policy, physics or technology, not all systems can easily share spectrum. Some systems may require interference-free spectrum to ensure operation is not negatively impacted or degraded. Systems that are integral to public safety, such as air traffic control radars, often require very high levels of protection.

Radar generally transmits very strong spectrum signals and receives its own reflected signals, which are incredibly weak. These signals often travel hundreds of miles over their reflected path, and only a minuscule amount of the original transmitted signal is returned to the radar. The high transmission powers of radar are prone to affect spectrum use that is within the transmission areas of radar, and radar is very susceptible to radio frequency interference when it is receiving its very weak returned signal. As a result, radar is generally allocated spectrum solely for radio-location purposes, and other uses of spectrum are not allowed within the same allocations.

While the preponderance of spectrum-dependent systems and equipment can share some use of the same radio frequencies, not every system can share with every other system. Some systems cannot successfully operate in the same allocated set of frequencies. Given the escalation of spectrum use throughout the world, the alternative to sharing is reallocation. Portions of the spectrum are reallocated to allow for multiple, new uses of the same spectrum.

Re-allocations may be implemented by the relocation of existing spectrum use out of one frequency band and into other frequency bands or by adding additional allocations within the same band. Re-allocations of frequency bands that displace existing spectrum use can create a cascading effect that can be extremely challenging, especially if the displaced users cause the users in other bands to be similarly displaced. The ripple of disruption can have unforeseen effects and costly consequences. Reallocation is very similar to rezoning a section of a city and forcibly relocating its residents. Even when done with the greatest skill, it can be a very disruptive process.

Electromagnetic spectrum is a finite resource in short supply. As the United States and many other countries are engaged in maximizing the efficient and effective use of spectrum, spectrum sharing and reallocation considerations and initiatives are addressed daily. And, due to the importance of spectrum in commerce, national defense and public safety, spectrum sharing and reallocation will continue for many years to come.

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https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=3013

30

Spectrum Reallocation: Challenges and Opportunities

"Few technological developments hold as much potential to enhance America's economic competitiveness, create jobs, and improve the quality of our lives as wireless high-speed access to the Internet," wrote President Obama in a memorandum issued June 28, 2010, titled "Unleashing the Wireless Broadband Revolution."

Now, more than ever before, the use of electromagnetic spectrum, aka radio frequencies, is recognized as having significant contributions to the nation's economy. We need only look around at the myriad wireless devices emerging into the market every day.

The President wrote: "America's future competitiveness and global technology leadership depend, in part, upon the availability of additional spectrum." The presidential memorandum directs the Secretary of Commerce to work with the Federal Communications Commission (FCC) to make 500 megahertz (MHz) of federal and non-federal spectrum available for wireless broadband use within the next 10 years.

The president's directed efforts are intended to make available additional radio frequencies to support and enhance mobile broadband capabilities throughout the United States to spur the economic capabilities of the country.

The memo states: "This new era in global technology leadership will only happen if there is adequate spectrum available to support the forthcoming myriad of wireless devices, networks, and applications that can drive the new economy."

E-commerce, distance learning, and a plethora of other wireless capabilities, not to mention cellular telephones, have dramatically modified private, public, and commercial interests and abilities in the United States. Wireless access is critical to commerce, education and security, and other vital capabilities in the United States, which are now affected significantly by spectrum use.

The two naval services within the Department of the Navy (DON) are also experiencing a dramatic increase in spectrum use. Spectrum enables a long list of Navy and Marine Corps capabilities, and their naval reliance on and requirements for spectrum increase continually.

The memo states: "The spectrum must be available to be licensed by the FCC for exclusive use or made available for shared access by commercial and Government users in order to enable licensed or unlicensed wireless broadband technologies to be deployed."

Recognizing the beneficial effects that spectrum has on the nation's economy, as well as the nation's security, as provided by the Navy and Marine Corps, the DON is supporting the Secretary of Commerce, through ongoing Department of Defense (DoD) efforts, to identify spectrum that may be made available to support the president's direction. The DON Chief

Information Officer's efforts in this regard are substantial.

The DON is one of the largest users of radio frequencies within the federal government, and its use of spectrum is extremely diverse. As a result of the DON's robust and various uses for spectrum, the DON CIO's spectrum team will conduct intensive analyses on a number of frequency bands to ensure the DON's existing capabilities are not degraded or eliminated when they are relocated to another frequency band, or when they share the use of a frequency band with non-federal users. "Spectrum and the new technologies it enables also are essential to the Federal Government, which relies on spectrum for important activities, such as emergency communications, national security, law enforcement, aviation, maritime, space communications, and numerous other Federal functions," the memo states.

The analyses consider and address complex governance, technical and operational issues, and the results are aggregated to provide decision recommendations to the Secretary of Commerce. However, a decision to reallocate federal spectrum used by the DoD, to non-federal uses does not solely reside with the Secretary of Commerce.

The National Defense Authorization Act for Fiscal Year 2000 (Title X, Sub-part G, Section 1062) requires that the Secretary of Commerce, the Secretary of Defense and the Chairman of the Joint Chiefs of Staff jointly certify that the replacement spectrum band provides comparable technical characteristics to restore essential military capabilities that will be lost when a federal frequency band is reallocated for non-federal use.

"The Secretaries of Defense, the Treasury, Transportation, State, the Interior, Agriculture, Energy, and Homeland Security, the Attorney General, the Administrators of the National

Aeronautics and Space Administration (NASA) and the Federal Aviation Administration, the Director of National Intelligence, the Commandant of the United States Coast Guard, and the head of any other executive department or agency that is currently authorized to use spectrum shall participate and cooperate fully," the president wrote.

The requirement, to jointly certify that federal spectrum reallocation will not result in lost or degraded military capabilities, underscores the fact that the nation's security is comprised of its economic and defense postures and capabilities. This is not a surprise within the DON. Throughout the DON's history, the naval services have capitalized on and employed technology advances that were created, whether in part or in whole, by commercial entities for economic purposes. With this in mind, the risk of losing spectrum within the United States, which is intended to energize wireless broadband use, must be viewed as a potential opportunity for yet another introduction of new and enhanced naval spectrum capabilities.

"As the wireless broadband revolution unfolds, innovation can enable efficient and imaginative uses of spectrum to maintain and enhance the Government's capabilities," the president wrote.

April-June 2011
https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2284

31

Increasing Spectrum Efficiency

Many forms of electromagnetic energy make up the electromagnetic environment, e.g., gamma rays, X-rays, ultraviolet radiation, visible light, infrared radiation, microwaves, and radio waves. This "energy" includes man-made emissions from communications equipment and systems, commercial systems, and electrical power lines and generators, as well as natural emissions from lightning, the sun, cosmic radiation, and other sources. Navigating this vast array of energy requires coordinated management activities across all functional areas within the Department of the Navy.

The goal of spectrum efficiency is to minimize electromagnetic environmental impact while maximizing operational effectiveness of this finite resource. The ultimate goal of spectrum users is to employ more spectral efficient systems. Efficient use of electromagnetic spectrum is critical for future spectrum sharing. While conceptually this may seem obvious, it is not easy to understand in practice. In this article, we explore what spectrum efficiency means and what challenges exist in measuring improved efficiency.

In its simplest form, efficiency is the ratio of the output to the input of any system. For spectrum dependent digital communications systems, efficiency is sometimes measured as bits per hertz. However, other measurement ratios apply for other spectrum-dependent systems. This difference presents a unique challenge in determining which system is using spectrum most efficiently.

In some cases, we avoid this challenge because separate portions of the radio frequency spectrum are allocated for specific systems to operate. For example, certain spectrum bands are allocated for radar systems and other bands are allocated for wireless networks. But there are many other cases in which one spectrum band is allocated to multiple uses. In those situations, without a common frame of reference or measurement, it may not be possible to determine which system is more efficient.

However, while determining and comparing absolute spectrum efficiency among multiple systems might be impossible, determining relative efficiency between systems could become a viable standard procedure.

Determining relative efficiency does not necessarily require a quantitative measure of efficiency. If the general concept of spectrum efficiency is understood, two systems might be compared based on a qualitative judgment that one is more efficient than the other, without a need to actually measure efficiency. For example, a person can hold two stones, one in each hand, and determine if one is significantly heavier than the other without weighing them. This form of relative comparison could become standard.

Since all electromagnetic systems must share the electromagnetic environment, a qualitative evaluation of spectrum efficiency might be: which system is the most effective in performing its function with the least impact on the electromagnetic environment. When two systems are compared using this measure, it may be possible to determine if one system is more efficient than another without requiring a quantitative measure.

Having a method of determining which system is more efficient than another also helps to improve spectrum efficiency over time. As a new system enters a spectrum band, there could be a requirement that it assert how it is more efficient than other systems in that same band. The new system may claim to have similar capabilities but less impact on the electromagnetic environment, or greater capabilities with similar impact on the electromagnetic environment. Ideally, the new system will have both greater capabilities and less impact.

While this method may not be an ideal solution to the challenge of increasing spectrum efficiency, it is an approach that could be implemented today and into the future, whether a method ever materializes of comparing significantly different spectrum dependent systems.

Spectrum efficiency is critical to enabling greater use of this finite resource. Increasing efficiency cannot wait for a one-size-fits-all definition or quantitative measurement approach that may never emerge. It is better to generally move in the right direction than to not move at all. By qualitatively comparing new spectrum-dependent systems with current systems, there is an opportunity to increase spectrum efficiency without precisely measuring it.

April-June 2016

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=7677

32

How One Idea Can Change the World

Every four years, nearly 150 distinguished ambassadors and more than 2,000 delegates from across the globe gather for the United Nations International Telecommunication Union's (ITU) World Radiocommunication Conference.

During this four-week marathon, committed delegations will scrutinize, debate, create and revise the international treaties that govern the regional and global use of electromagnetic spectrum or radio frequency spectrum.

The final acts of World Radiocommunication Conference will receive little if any fanfare beyond stakeholder communities, such as those engaged with cellular telephone service, advanced wireless services and other spectrum-related services, even though the results of this gathering will have direct, significant and global implications to all of us who depend on wireless capabilities that can only be enabled by use of the electromagnetic spectrum, and in the 21st century, it is impossible to imagine a life that isn't directly, or indirectly, dependent on the electromagnetic spectrum.

Much of our modern way of life would be impossible without access to the electromagnetic spectrum. The Department of the Navy (DON) is highly dependent on spectrum-enabled capabilities that provide a multitude of the Navy's and Marine Corps' communication, sensor, intelligence, combat and other capabilities that are vital to the naval services' ability to meet their global responsibilities.

Due to the significant implications to Navy and Marine Corps spectrum capabilities, the DON either closely monitors or actively participates in every WRC preparatory venue to protect the naval services' equities or to advocate for changes that enhance their capabilities.

Additionally, the DON ensures its interests and positions with WRC issues are known and aptly represented by the United States delegation, which includes personnel from the Department of Defense, as well as the DON.

The issues that will be decided at WRC are incredibly diverse as they have been in past conferences. Items on the WRC agenda of particular interest to the DON include current, emerging and future radio applications; unmanned aircraft systems; ship and port safety systems; sea surface radar; and software defined radios. The complete WRC agenda will be available on the ITU Web site at www.itu.int/.

It is inarguable that one of the most important WRC agenda items is the one that requests and ultimately determines future agenda items for later WRCs. Proposed agenda items can be submitted by all participating delegations.

However, the genesis of any particular agenda item is often traced to one or more individuals in organizations involved with research, development, or the operation of spectrum-enabled capabilities. More often than not this can be traced back further to one idea — one idea that ultimately will change the world.

As such, DON program managers, spectrum managers and anyone else in the department associated with research, development, acquisition, governance, or the operation of spectrum-dependent systems or devices, has an opportunity to propose issues that may result as a WRC agenda item.

International governance, spectrum services, radio frequency interference and emerging technologies are just a sampling of issues that “bubble up” from individuals with a regional or global spectrum challenge or a spectrum solution.

It is through the WRC that DON personnel are able to defend and advance the capabilities of the Navy and Marine Corps by improving or modifying the world’s use of spectrum. Regulations and procedures for frequency management, in the United States, and the host nations in which our troops train, are grounded in the international treaties that are made and modified at the WRC.

American anthropologist Margaret Mead said, “Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it’s the only thing that ever has.”

January-March 2009
https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2713

33

International Spectrum Engagement

The Department of the Navy's (DON) engagement in the United States spectrum regulatory environment has been discussed in previous articles. However, the DON has many facilities and operations that are not under the umbrella of domestic regulation. The complexity of acquiring spectrum access for these situations increases and is often multiplied when Navy and Marine Corps operations are located within, or even transiting, foreign nations. As a result, the DON is globally engaged with various multinational organizations to accommodate the international presence of our naval forces and to nurture the availability of spectrum resources.

Internationally, many organizations impact spectrum availability. Some are obvious, such as the United Nations International Telecommunications Union (ITU) Radiocommunications Sector (ITU-R), while others may not be as apparent, but they are still critical to DON spectrum access. To better acquaint readers with the DON Chief Information Officer's (CIO) sphere of engagement, a list of several of the organizations in which the DON actively participates and contributes to enhance access to spectrum follows.

Combatant Commands

The July 2008 CHIPS article titled "Military Coalition Frequency Management" offered some background on the environment in U.S. European Command and the DON's coordination with the North Atlantic Treaty Organization (NATO) members. While the combatant commands have similarities, their policies, guidance and procedures for spectrum usage vary significantly due to differences in area of responsibility. Each combatant command has a structure to act as an emissary to sovereign nations in its area of responsibility to synchronize spectrum access.

Spectrum planning for naval operations in multiple geographic areas in a single deployment is a challenge. Operational engagement with the geographic combatant commanders is invaluable in managing these challenges.

North Atlantic Treaty Organization

Perhaps the most recognized multinational body in the Western world is NATO. North Atlantic Treaty Organization nations and partner countries cooperate through NATO's Frequency Management SubCommittee (FMSC) to establish overarching policy for parts of the radio frequency spectrum used by the military.

One particular responsibility of the NATO Frequency Management Sub-Committee is establishing policy for the military management of the ultra high frequency band between 225 and 400 megahertz, widely used for military aircraft, naval and satellite communications.

Combined Communications-Electronics Board

The Combined Communications- Electronics Board (CCEB) is a five-nation (Australia, Canada, New Zealand, the United Kingdom and the United States) joint military communications-electronics organization whose mission is the coordination of military communicationselectronics matters among its member nations.

The CCEB routinely develops strategic plans that provide the roadmap to achieve future interoperability. Following the establishment of the CCEB, discussion and a vision to deliver battlewinning maritime command, control, communications and computer (C4) interoperability led to an effort to align naval communications policies and prevent any barriers to interoperability with the imminent introduction of sophisticated new communications equipment. The DON is involved in the CCEB to support continued coalition interoperability at sea.

Gulf Cooperation Council

The Gulf Cooperation Council (GCC) was established in 1981 between Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates as a regional common market and defense planning council. The geographic proximity of these countries and their adoption of free trade economic policies are factors that encouraged them to establish the GCC.

In 1991, multilateral security commitments between the United Kingdom, the United States and Kuwait created a liaison relationship to the GCC. The extensive presence of United States Navy resources in the Persian Gulf necessitates that the DON support careful and continual coordination.

European Conference of Postal and Telecommunications

Administrations (CEPT)

CEPT is acknowledged by the ITU-R as a composite representative of many European administrations. Bodies like CEPT are given special recognition and negotiation status during major ITU radio regulation conferences. While there is some CEPT membership overlap with NATO, not all CEPT members are NATO partners. The DON works as an adviser to many of the CEPT groups, developing regulatory proposals. Such proactive efforts attempt to mitigate serious disagreement at the final stages of radio regulation modification.

Organization of American States (OAS)

Similar to CEPT, the Organization of American States is a regional body with members from North, Central and South America. The OAS is represented at the ITU-R by its Inter-American Telecommunication Commission Permanent Consultative Committee for Radiocommunications and Broadcasting. The DON works closely with the OAS Inter-American Telecommunication Commission during preparatory meetings to resolve spectrum issues and to develop strategies and Inter-American proposals to formally liaise with other regions and introduce issues or proposals at ITU radio regulations conferences.

Technical and Standards Bodies

Spectrum-dependent technology can be leveraged for DON requirements or become a strident competitor for spectrum resources. The standards by which the systems operate are as critical to the DON as the international rules and regulations governing their use. The DON CIO maintains an active engagement in international standards bodies to manage the creation of specification standards that set the foundation for global technological evolution.

Institute of Electrical and Electronics Engineers (IEEE)

Long recognized as an active body that introduces various communication and computer-related concepts, the Institute of Electrical and Electronics Engineers is an avenue for the DON to influence early decisions on technology trends. A familiar wireless networking standard, 802.11, is an example of an IEEE standard. Areas such as the implementation of software defined radio and cognitive radio systems are immediate examples of recent DON influence and success.

International Organization for Standardization (ISO)

The ISO is an independent group that encourages harmonization of best practice concepts from all regions and nations. Specifically, the global intermodal (ship, rail, truck and air) transfer of goods, which impacts the safety of U.S. harbors and airports, is a high priority interest. The DON CIO serves as an advocate for the adoption of standards that the ITU-R can support with spectrum allocations, and the International Maritime Organization can merge into its policies and procedures.

This is just a few of the international governance bodies in which the DON CIO engages to assure international treaties, standards, processes and regulations are favorable to naval operations while supporting the global electromagnetic environment. The DON CIO is a dynamic leader and trusted partner in various spectrum-related policy and strategy groups. The ability to deliver U.S. naval forces spectrum today and in the future is critically dependent upon these ongoing engagement efforts.

October-December 2010

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=2346

34

Policy Leads Innovation

Often what appears to be innovation is actually the result of incremental change applied to a problem over a long period of time. With enough time, and enough persistence, anything that is physically possible can and likely will be accomplished. The challenge for policymakers is to lead these changes, rather than lag behind them.

Too often policy is created as a reaction to change, rather than in anticipation. This can be especially problematic if policy must change to enable innovation to thrive. And the results can be catastrophic for promoting innovation when enabling policies takes years, or even decades, to enact. Innovation can be delayed, or even stalled completely, unless policymakers make an extraordinary effort to lead, rather than follow innovation.

An even greater challenge than anticipating innovation decades in advance is garnering support to begin these processes with little or no functioning examples of an innovative technology or concept. That challenge is further amplified when technological cost and complexity are inconceivable today, despite reasonable assumption that both will be reduced in the ensuing decades.

The DON Spectrum Team addresses these challenges every day. Global spectrum policy is established by a special body under the United Nations, the International Telecommunications Union Radiocommunication Sector (ITU-R). Policy is published in the form of an International Radio Regulations treaty. Changing Radio Regulations is done via the World Radiocommunication Conference (WRC), which meets every four years in Geneva, Switzerland.

All 197 member nations of the ITU-R must reach consensus before Radio Regulations are changed. For example, the next WRC is in 2019 (WRC-19). Preparation for every WRC is continuous. Changes to the International Radio Regulations typically take 8 to 12 years from preliminary proposal to final adoption; some changes may take 20 years to accomplish.

The agenda for the next WRC proposed changes to the Radio Regulation treaty were established at the last WRC, and many of the agenda items were first proposed at the previous WRC, or earlier.

After the World Radiocommunication Conference adopts changes to the Radio Regulations, implementation may take additional years or decades for the international community to implement new regulations and adapt legacy technology. The entire process, from conception to adoption, typically spans decades, and may be as long as half a century to completion. These long lead times are not unique to spectrum management; inevitably, they are common among all technologies that require global policy to implement.

Policymakers must maintain a broad vision of where innovation will occur. Knowing what specific technology will bring innovation to fruition is less important than understanding when innovation will mature and how it will be implemented. For global spectrum policymakers, timing is critical. Reacting to innovative solutions when they are brought to market is too late. Even reacting to conceptual and experimental ideas may be too late — if policymakers cannot anticipate and prepare for the change.

Within the federal government, incentives to accelerate research, development, and procurement may bring an innovative idea to fruition long before global policies can be changed. Thus, even when policymakers take steps to lead, they may still lag behind innovation. For policy to lead innovation, a policymaker must anticipate the innovation timeline and understand the policy timeline — then initiate policy change far enough in advance to enable global change before it becomes critical to do so.

What may seem like an impossible or improbable goal is actually achievable. Nearly every global innovation we have today was broadly forecast decades before broad acceptance. Technology policymakers must look to forecasts, engage forecasters, and seek to understand their vision of the future that will eventually become reality. In this way, policy will lead innovation, and as a result, policy will advance innovation rather than impede it.

The DON Spectrum Team is continuously seeking the seeds of electromagnetic innovation to understand the state of the art and the art of the possible for spectrum-dependent technology that will be available decades from now. Working within the international, national, federal, and military spectrum policy processes, this team persistently strives to remove policy and regulatory barriers that would impede innovation from enhancing operations.

April-June 2017

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=8944

35

Leveraging Lean Six Sigma

The Department of the Navy Chief Information Officer (DON CIO) embarked upon a Lean Six Sigma (LSS) project to improve data collection and dissemination for rapidly procured DON spectrum-dependent equipment being introduced into theater for the global war on terrorism (GWOT).

The rapid procurement of communications-electronics (CE) equipment presents significant challenges for deployed Marine Corps and Navy forces. Devices and systems fielded without sufficiently accurate spectrum supportability data often cause radio frequency interference to existing communications, navigation and other mission-critical capabilities.

Rapidly procured CE devices requiring electromagnetic spectrum (radio frequencies) include radios, unmanned aerial and ground systems, and radio frequency jamming devices and systems. Office of Management and Budget Circular A-11, Department of Defense Directive 4650.1 and Secretary of the Navy Instruction (SECNAVINST) 2400.1 require the program office or procuring agent to verify that spectrum-dependent systems are “spectrum supportable.”

Current spectrum supportability determination processing can take between two months and two years. A more responsive, streamlined process is needed that provides sufficient spectrum-dependent data to conduct operational assessments that identify spectrum conflicts and assure spectrum access.

Subject matter experts from the DON CIO, Chief of Naval Operations, Headquarters U.S. Marine Corps, Office of the Assistant Secretary of Defense (Networks and Information Integration), Navy and Marine Corps Spectrum Center and U.S. Central Command (CENTCOM) actively participated on this LSS project.

The team identified performance measures and associated metrics related to spectrum supportability that are aligned to the DON objective to provide critical GWOT support. These included a Cycle Time Metric and Safety Metric.

Cycle Time Metric

Significantly reduce process cycle time so that it coincides as closely as possible with the time-frame of spectrum-dependent rapid acquisitions (often completed within one to six months of a validated “Urgent Operational Needs Statement” from Operation Iraqi Freedom and Operation Enduring Freedom forces).

Safety Metric

Reduce the amount of spectrum-dependent systems and equipment entering CENTCOM’s area of responsibility without sufficient data.

As the Spectrum LSS Project Team mapped the current “as-is” process, they immediately addressed glaring gaps and overlaps. They identified four “quick wins” to improve the spectrum supportability process and fast track the availability of critical spectrum data to forward deployed naval warfighters, before and during the fielding of rapidly procured spectrum-dependent CE systems and devices. These quick wins are being executed while the project continues.

Quick Win No. 1

A checklist, "Minimum Technical Requirements For Rapidly Procured Spectrum-Dependent Equipment," identifies the minimum technical spectrum requirements that must be identified, known and available before and during the fielding of rapidly procured spectrum-dependent equipment.

This checklist does not eliminate the requirement to complete appropriate spectrum supportability documents such as the DD-1494s. The checklist is available on the DON CIO Web site at www.doncio.navy.mil/.

Quick Win No. 2

Rapid publication of technical data to the Navy's Afloat Electromagnetic Spectrum Operations Program (AESOP) and the Marine Corps' System Planning, Engineering and Evaluation Device (SPEED) databases, before the joint review and federal certification process.

The early dissemination of critical data will enable naval operational forces to perform automated prediction and engineering that will enhance CENTCOM's operational capabilities. It will help mitigate the time lag associated with data injection to spectrum databases, while leveraging existing naval databases that are widely used throughout the Department.

Quick Win No. 3

The addition of language in acquisition policy to mandate contractual requirements to provide technical spectrum data to alleviate excessive wait times associated with data requests to vendors. A requirement statement will be included in the next update of SECNAVINST 2400.1, “Electromagnetic Spectrum Policy and Management.”

Quick Win No. 4

Clarifies the requirement to process equipment that uses legacy wave-forms or has been issued a Federal Communications Commission identification number through the federal “certification” process. This will reduce DON spectrum engineering workload and result in a streamlined spectrum supportability process to better support the DON acquisition communities.

Like Quick Win No. 1, it does not eliminate the requirement to complete the DD-1494. Although the LSS project is in the “improve” phase of the “define, measure, analyze, improve, control” process, it has not slowed down the execution of the quick wins.

One lesson learned is that LSS empowers a team to challenge the status quo and make a difference. This LSS project is scheduled to complete the “control” phase in May 2008.

The quick wins together with the full LSS project underway have made and will continue to make great improvements to the fielding and supportability of spectrum-dependent communications and electronics equipment that support warfighters.

April-June 2008
https://www.doncio.navy.mil/chips/ArticleDetails.aspx?ID=2813

36

The DON Electromagnetic Spectrum Campaign

The Navy and Marine Corps' role in the global war on terror requires the rapid development of new capabilities to defeat emerging threats from the enemy, and many of these capabilities make use of the electromagnetic spectrum (radio frequencies).

Unmanned aerial systems, unmanned ground robotics and radio frequency jammers are samples of enhanced spectrum-dependent tools being used by deployed naval forces. As such, the Department of the Navy (DON) continues to increase its reliance on the use and access to spectrum. Today, spectrum is as important to Navy and Marine Corps forces as their weapons and communications.

Acknowledging the impact electromagnetic spectrum has on Navy and Marine Corps capabilities, the DON issued the first Electromagnetic Spectrum Campaign Plan. The plan establishes departmental goals and supporting objectives representing a holistic approach to maintain access to spectrum and ensures the DON makes efficient and effective use of this finite critical resource.

The campaign plan, available for download at www.doncio.navy.mil, identifies and addresses five broad, overarching goals holistically encompassing the management and use of spectrum. These goals represent the DON's efforts in the spectrum arena for the next year. The following areas are addressed.

Technology and Transformation

Over the past three decades, technology has evolved at a feverish pace and the DON's use of spectrum to support wireless capabilities has escalated proportionally. Today, technology provides the ability to receive e-mail on portable, handheld devices; make cellular telephone calls from anyplace on Earth; track and forecast the paths of hurricanes and tropical storms with great accuracy; and a vast number of other capabilities that are all enabled by the electromagnetic spectrum.

As technology continues to advance and the demand for spectrum increases, the DON must manage and use spectrum as efficiently and effectively as possible.

Federal, National, and International Spectrum Policies

Much of the Navy's and Marine Corps' use of spectrum is reliant upon host nations allowing U.S. forces to use spectrum for their missions. International spectrum policy changes can have a dramatic impact on the Navy and Marine Corps' capabilities. The Department recognizes this importance and strives to advocate policies that support the global efforts of the naval services.

National and federal spectrum policies also impact Navy and

Marine Corps training within the United States and its possessions, and similar to the Department's international advocacy, the Department supports national and federal spectrum policy that provides realistic, unrestricted training opportunities.

Spectrum-Related Administrative Actions

Federal administrative actions ensure the efficient use of spectrum. Administrative actions within the Department of Defense spectrum community include coordination of system characteristics to support the assignment of frequencies to Navy and Marine Corps forces. These actions are essential to sustained, interference-free use of spectrum critical to warfighters.

The DON's timely and accurate spectrum-related administrative actions identify the Navy and Marine Corps as good stewards of a host nation's spectrum resources.

Department and Service Spectrum Publications, Directives and Policy: A number of publications, directives and policies from the Department and its naval services address, in whole or in part, spectrum. The rapid acceleration of technology can result in policy and governance lagging behind the systems they affect. As such, the spectrum publications, directives and policies within the DON must be regularly reviewed to ensure that they adequately and accurately address spectrum processes and departmental responsibilities.

The benefits of up-to-date publications include coordinated actions throughout the Department that provide spectrum when and where it is required by naval warfighters.

Personnel Training and Spectrum Tools: The most important asset of the DON is its personnel. They must receive the very best, most realistic spectrum training possible and have access to the best automated spectrum tools to remain the world's finest fighting naval service in the world.

In addressing these five areas the Department is devoting significant resources to ensure efficient management and effective use of spectrum. Spectrum enables a multitude of capabilities within the naval services, many of which are critical to mission success and safety. Therefore, spectrum requirements are addressed in acquisition, operational planning, command and control, and all other DON functional areas relying on wireless, real-time, spectrum-enabled capabilities.

The Department's operational community, program managers, installation personnel and other spectrum stakeholders must consider during the planning stages, how spectrum-reliant systems will be supported.

July-September 2007
https://www.doncio.navy.mil/chips/ArticleDetails.aspx?ID=2900

37

Transforming Spectrum Management

Emerging technology has always compelled traditional spectrum management processes to adapt and evolve. The 2012 International Telecommunication Union World Radiocommunication Conference issued new international radio regulation treaty language regarding software defined radio and cognitive radio systems.

During the coming months, the United States and each member nation of the International Telecommunication Union will begin incorporating the decisions made during the conference into their national regulatory processes. For the United States and other nations that seek to assure their communications license holders access to specific electromagnetic spectrum, these new technologies will challenge the stability of the current spectrum management business paradigm. For industry professionals who assure their customers access to the electromagnetic spectrum, the emergence of these new technologies also poses a challenge to the spectrum management process.

In a software defined radio, the software defines the characteristics of the radio, and software wave-forms may be reused and ported onto different radio hardware similar to computer applications. Traditional hardware components are replaced with embedded computing devices.

Cognitive radio systems obtain knowledge and then adjust their operational behavior based on that information. While neither of these technologies is in widespread use today, they are already affecting the traditional concepts of equipment certification and frequency assignment.

There are several steps in the Department of the Navy's spectrum dependent systems development process during which the effects of the technology under development in the electromagnetic environment is assessed. The system is certified to function without harming its intended operational electromagnetic environment or exceeding a rigid set of operational criteria. Once deployed, radio frequencies are assigned to that device for specific operations within prescribed parameters for a specific geographic location.

Software defined radios present a challenge for equipment certification processes because their specific operational parameters may not be determined until a software profile is loaded into a device. As the term software implies, this new generation of radios is not restricted to operating in the historical structure determined by design and manufacturer constraints. The profiles may vary greatly depending on the flexibility of the software defined radio.

One military software defined radio program, the Joint Tactical Radio System (JTRS), has been challenging the equipment certification paradigm for more than a decade. The obvious benefit of this technology is enhanced mission capabilities. The electromagnetic characteristics of JTRS radios are dependent on specific waveform software profiles installed in the hardware platform. The permutation of multiple platforms and multiple wave-forms does not fit within the paradigm of a traditional hardware radio with finite operational characteristics.

Cognitive radio systems present a challenge to spectrum management during the frequency assignment process. In its extreme implementation, a cognitive radio system automatically adapts its communication parameters to network and user demands based on its interpretation of available spectrum. As the electromagnetic environment changes, the cognitive radio system's behavior may change as well.

Dynamic frequency selection technology is an early indication of a cognitive radio's capabilities for spectrum sensing: detecting the unused spectrum and sharing it without harmful interference with other users. Depending on the local electromagnetic environment, a dynamic frequency selection device will modify its behavior to operate on some frequencies while avoiding others. During the past decade, dynamic frequency selection systems have been introduced into some Wi-Fi technologies. This is a primitive example of cognitive radio systems but, like JTRS, it too has challenged traditional spectrum management practices.

The transformation of spectrum management business processes will be led by the intersection of technological capabilities and regulatory requirements. Spectrum management business processes will harness these two forces to put cognitive radio systems and software defined radios into the hands of war-fighters. Procedures for spectrum management will not only adapt to incorporate these new technologies, they will transform as these technologies bring new concepts and capabilities to spectrum management.

Spectrum management business processes must incorporate aspects of behavior enforcement to ensure that the technology acts the way operators want it to in a given situation, as well as support a level of autonomy for the technology to make decisions without human intervention, while enabling configuration management in near real-time. The business process will evolve from a system of strict predetermination toward one based on trust.

April-June 2012

https://www.doncio.navy.mil/chips/ArticleDetails.aspx?id=3893

38

Plotting a Spectrum Revolution

Adm. Vern Clark wrote about “revolution” while serving as Chief of Naval Operations. Today, the retired CNO still refers to revolution when publicly speaking about his efforts to change and improve business processes within the Navy. He confessed that, even as the second longest serving CNO, he didn’t have time for “evolution,” which is why he unapologetically chose revolution.

Evolution and revolution are very different processes. While evolution is a process of gradual and relatively peaceful social, political or economic advance, revolution is a sudden, radical and absolute change.

Evolution in business processes provides time for people to accept slow methodical changes. On the other hand, revolution is generally difficult for people to accept due to rapid change and is often viewed negatively.

Revolution is used to describe change in many business processes. In fact, modern computers and software are results of a revolution that led to the Silicon Valley high-tech empires in Northern California.

The convergence of cellular technology, the Global Positioning System (GPS) and a long list of services, technologies and devices are setting the stage for a wireless revolution that will influence our personal lives, business processes and the capabilities of the Marine Corps and Navy, in such a way not seen since the introduction of modern warfare.

The Marine Corps and Navy have global responsibilities, and they require a significant number of radio frequencies to conduct their worldwide operations. All radio frequencies are recognized by international law as belonging to each and every nation.

U.S. forces face access issues in each country in which they operate due to competing civilian or government users of national spectrum allocations.

For example, when the Marine Corps and Navy are operating in Japan, the Japanese government regulates the radio frequencies U.S. naval forces can use. The same is true for Australia, Republic of Korea and all sovereign nations.

But even though radio frequencies are allocated, a large portion of the assigned spectrum is used sporadically, and there are wide variations in the use of assigned spectrum. The limited available spectrum and the inefficiency of its usage demands a new methodology to exploit existing wireless spectrum "opportunistically."

The wireless revolution is just beginning. A number of radical changes in the use of the electromagnetic spectrum, or radio frequencies, will soon have "dynamic" effects on naval capabilities. Dynamic Spectrum Access (DSA) refers to radios and other wireless capabilities that dynamically adjust to the spectrum environment and access radio frequencies that are unused or underused.

Access to spectrum, along with the corresponding capabilities and bandwidth may, by today's standards, be almost limitless. The Defense Advanced Research Projects Agency (DARPA) has developed DSA capability known as "Next Generation" or "XG," which promises significant benefits to forward deployed Marines and Sailors. Commercial companies are also developing DSA capabilities.

The goals of the XG program are to develop both the enabling technologies and system concepts, along with new wave-forms to provide dramatic improvements for assured military communications in support of worldwide operations, according to DARPA.

The XG program approach plans to investigate methods to leverage the technology base in microelectronics, with new wave-forms and medium access and control protocol technologies, to construct an integrated system.

The proposed program goals are to develop, integrate and evaluate the technology to enable equipment to automatically select spectrum and operating modes to minimize disruption to existing users and to ensure that U.S. forces can fully exploit their superiority and investment in information technology.

DSA will revolutionize naval wireless capabilities by providing greater access to limited spectrum resources. Today, there are considerable obstacles to employing DSA. International and national spectrum governing bodies control spectrum use through rigid radio frequency allocations that often result in one frequency per wireless use.

The benefits of DSA to the Marine Corps and the Navy will be impressive, but changes to national and especially international spectrum governance are inexplicably slow.

The DON Spectrum Team is "plotting a spectrum revolution," and we are not alone. We are part of a global spectrum revolutionary movement of industry, private consortia and other progressive nations on the leading edge of technology.

A revolution is seldom accomplished alone.

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39

Unmanning Unmanned Systems

The growth and diversity of military unmanned aerial vehicles (UAV) in the first decade of the 21st century has been unprecedented. To say that UAVs: "continue to be the most dynamic growth sector of the world aerospace industry" understates the obvious. "An insatiable demand for UAVs is fueling massive growth within this market," said Mr. Larry Dickerson, senior unmanned systems analyst for Forecast International. "No matter how many UAVs are built, military agencies want more."

Dickerson notes that a few years ago, UAV contracts in the millions of dollars were big news; now these awards are in the billions. "In addition to procurement, research funding for UAVs could exceed $20 billion through 2018," he added.

And while UAVs may be in the spotlight, unmanned systems aren't limited to air. Unmanned ground, air and sea systems are all force multipliers. They reduce the dangers to warfighters and represent a critical evolution in how the departments of Defense and Navy deploy military technology. But are unmanned systems truly unmanned?

More often than not unmanned systems are remotely operated via a strict and bandwidth-intensive electromagnetic tether. Radio communications between the unmanned system and a control station sequester the operator from the vehicle, but do not truly remove the man from the unmanned system. Maintaining positive control over a remotely operated vehicle requires highly reliable yet complex radio links. It also limits the capabilities of the system to those actions a remote operator can control.

Technological advances will eventually enable unmanned systems to evolve beyond their current remote-control architecture, an evolution necessary if just to somewhat relieve the burden these systems tend to impose on a finite, crucial, congested and contested resource: the electromagnetic spectrum. In this article we will examine some of the challenges as we remove the man and woman from unmanned systems and consider the future of autonomous unmanned vehicles (AUV).

It is generally accepted that a fully autonomous system would have the ability to: Gain information about the environment; Work for an extended period without human intervention; Travel from point A to point B to point C, etc., without human navigation assistance; Detect objects of interest such as people and vehicles; Avoid situations harmful to people, property, or itself(except when part of its mission); and Defend and repair itself without outside assistance.

An autonomous system may also be able to: Learn or gain new capabilities without outside assistance; Adjust strategies based on its surroundings; and Adapt to surroundings without outside assistance.

Why can unmanned systems be such spectrum gluttons?

Unable to attach a 10,000-kilometer fiber optic cable, we link the unmanned system to manned support via bandwidth intensive wireless data links. Human eyes are replaced by numerous wide-band streaming video channels. Instruments and gauges are monitored by operators oceans away.

Unmanned surveillance systems transferring multi-spectral data from infrared and ultraviolet sensors take up a staggering amount of bandwidth, as do both standard and high-speed, full motion video. Also, consider that to reach a geographically remote control station the unmanned system mission and control data must be retransmitted, usually via satellite, effectively doubling the bandwidth required. A Predator, Reaper or Global Hawk UAV, for example, can easily take up to a full transponder on a satellite to transfer data.

"The demand is huge because commanders no longer want pictures taken last week; they want streaming video with enough clarity and fidelity to anticipate the actions of the enemy," said retired Army Maj. Gen. Robert Scales, a military historian. "Thus, we are not even within five percent of what's really needed."

A Pentagon presentation in 2008 showed demand for video was more than four times the supply and increasing exponentially. Currently, tactical Predators and Reapers supply more than 400 hours of video daily. Some of these warfighter platforms have expanded to carry 10 cameras today and will mount up to 30 by 2011, adding to the profusion of video and further exhausting scarce electromagnetic assets.

Beyond the immediate issue of bandwidth and spectrum constraints, the ability to leverage the host of imagery and signals intelligence is quickly becoming unmanageable. Much of the imagery gathered during collection is either lost to information overload because humans cannot adequately process it in real time, or it serves little purpose since today's processing power and analytical algorithms are inadequate to meet either supply or demand. As data gathering exponentially increases, hiring more analysts is not a viable option.

Future development must not simply focus on greater autonomy in the unmanned vehicle. We must also recognize that both real-time and post-operation analyses are two sides of the same coin. Some type of autonomous analysis needs to take place on the vehicle if we hope to sever the constant link between platform and operator. The system could still keep a human in the loop for firing at urban ground targets. The vehicle would only need to share relevant imagery and wait for permission to fire.

The primary goal of autonomous unmanned systems must remain reducing the danger to the war-fighter. But autonomous unmanned systems must have a secondary goal of increasing the efficacy of our forces as a force multiplier of intelligence, surveillance and reconnaissance (ISR) assets. And by cutting the electromagnetic umbilical cord, autonomous unmanned systems will be much more spectrum efficient.

Lastly, there will be eventual cost savings of autonomous over manned and unmanned based systems — something we must consider in a budget constrained environment. The MQ-1 Predator's role as a force multiplier usually goes unquestioned until one considers the footprint that accompanies the system.

The U.S. Air Force fact sheet notes that the typical "fully operational system consists of four aircraft (with sensors), a ground control station, a Predator Primary Satellite Link, or PPSL, along with operations and maintenance crews for deployed 24-hour operations."

For those four aircraft, this involves 55 or more personnel. And while some personnel would be needed for logistics and maintenance of any system, roughly half of that 55-person footprint is made up of flight crew. As vehicle control becomes autonomous, so too must the analysis and maintenance.

While the full realization of autonomous systems may be decades away, we need to take steps toward developing technology in this direction today. First and foremost are the mathematical, software and processing developments allowing automated systems the necessary on-board intelligence to be autonomous?

In the same way, with the likely wide dispersion of these platforms, and the need to work in concert with a host of other varied platforms, development toward secure interoperability standards for the autonomous systems is also a must. The sum of human regulation has been based on managing the actions of people or the consequences of those actions. Ultimately a person is held accountable because it is generally understood that machines cannot be responsible for their actions.

Some of these rules and regulations will require significant, if not total, overhaul to accommodate the productive coexistence of people and autonomous systems. But if the world is to progress beyond remote control and overcome the spectrum constraints limiting unmanned vehicles, we must address these larger challenges.

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40

A New Century for Unmanned Maritime Systems

Today's unmanned vehicles can trace their roots back to the inventor of alternating current (AC), Nikola Tesla (1856-1943). Renowned for his work with AC motors, dynamos, hydroelectric power and X-ray technology, Tesla found time to invent the world's first practical remote-controlled unmanned vessel. In 1898, Tesla was granted a U.S. patent for a "Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles." The patent covered "any type of vessel or vehicle which is capable of being propelled and directed, such as a boat, a balloon or a carriage."

During an electrical industry trade show at Madison Square Garden in New York, Tesla publicly demonstrated his unmanned ship in a large tank of water. The historic event created some sensation about his method of using radio for command and control.

While adoption of unmanned aircraft is reaching epic proportions, unmanned maritime systems (UMS) have had slower progress. But during the next decade, a significant increase in the application of UMS is anticipated. Unmanned maritime systems, which include surface and underwater vessels, will provide enhanced capabilities to maritime administrators and operators with a significant reduction in costs. Studies predict an investment of billions of dollars will create a new generation of unmanned vehicles for various land, sea and air functions.

Applications for UMS can be classified into two main groups: commercial and governmental. Commercial applications will provide services to be sold by contractors in the course of carrying out normal business operations. Governmental applications, on the other hand, will ensure public safety and security by addressing different emergencies, issues of public interest and scientific matters.

Unmanned maritime systems are especially practical for hostile maritime environments in which deploying a crewed vessel is ill-advised. Hostile waters include high threat environments or areas contaminated by nuclear, biological or chemical agents. A key challenge for the global introduction of unmanned maritime systems is reassuring all maritime administrations and organizations that operations will integrate seamlessly into current manned maritime procedures and that UMS operations are safe.

Another critical priority for operating unmanned maritime systems is the seamless integration into the global maritime communication environment. Unmanned maritime systems will use the same equipment as manned vessels to communicate with vessel traffic control. However, due to the remote nature of human interaction, command and control are vital to operating unmanned maritime systems and will influence the eventual development of composite electromagnetic spectrum requirements.

Like many current unmanned aircraft systems, UMS command and control will be transmitted via radio frequency links between the control station and the unmanned systems. For safe operations of an unmanned maritime system, highly reliable radio communications between the UMS and the maritime control station are required to support sense and avoid functions. In the end, unrestricted and autonomous unmanned maritime systems operations will rely on critical communications.

Current traffic management relies heavily on the internationally used Automatic Identification System. AIS is a tracking system used on ships and by vessel traffic services for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS base stations. The AIS provides information such as vessel unique identification, position, course and speed. New operational requirements for a future maritime data link environment will need to be developed. In some environments, additional radio frequency links called vessel traffic control relay will be required to relay communications received and transmitted by unmanned maritime systems.

Reliable radio frequencies to support relayed command and control are vital and must be considered along with the "sense and avoid" support requirement. These communications are especially critical for safe navigation in high-traffic maritime areas. In the near future, international standards may be necessary to develop these types of communications.

Sense and avoid corresponds to the piloting principle "see and avoid," which is used in all situations where a vessel's operator is responsible for ensuring adequate separation from nearby vessels, terrain and obstacles, including weather. To determine appropriate spectrum characteristics related to sense and avoid, two aspects must be considered.

First, all radio frequency equipment designed to collect raw data related to the "sense" function will have identified requirements specified by the planned radio services. For example, UMS radar equipment will operate in internationally allocated radio-determined frequency bands. The data derived by the sensors could either be directly processed inside a UMS or transmitted to the maritime control station for processing. Second, sense and avoid system functions will be continually or regularly checked at the maritime control station for proper operation. Sense and avoid equipment parameters may also be modified by a maritime control station and transmitted back to an unmanned maritime system depending on the area, weather conditions or level of autonomy.

Bidirectional sense and avoid communications between a maritime control station and an unmanned maritime system will require two distinct sense and avoid information streams. A data down-link will allow the maritime control station to control sense and avoid operations according to local conditions, while a data up-link from a UMS to a maritime control station will provide feedback that the sense and avoid functions are operating properly.

As with current unmanned aircraft systems, the need to send sense and avoid video streams must also be considered. Similar to command and control, sense and avoid data spectrum requirements must be compliant with future standards for the safe operation of an unmanned maritime system in areas under the responsibility of maritime authorities.

Safe operations of unmanned maritime systems may also require alternative back-up communications to ensure high reliability of critical communications links. An unmanned maritime system must be able to operate in both high and low density sea environments. The vessel traffic control system may not be able to restrict an unmanned maritime system to low-density space. Larger systems are likely to be equipped with terrestrial communication capabilities such as geostationary satellite links. However, the impact of latency on unmanned maritime systems' command-and-control systems will be critical when considering the safety of operations.

While today's 21st century UMS technology has developed from Nikola Tesla's 19th century vision, it remains an emerging technology. Many challenges, including the operational complexities of managing radio frequency electromagnetic spectrum, must be overcome for unmanned maritime systems to become commonplace in commercial and governmental applications. The DON Chief Information Officer maintains continual national and international engagement in electromagnetic spectrum and maritime regulatory bodies to ensure the success of naval UMS for our Sailors and Marines.

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41

Flocking, Herding and Schooling within Interconnected Intelligent Autonomous System

The eventual introduction of interconnected intelligent autonomous systems, or interconnected yet independent systems run by artificial intelligence, will require us to think differently about system behavior in the future. For spectrum-dependent systems, this will be especially challenging since behavior in the electromagnetic environment isn't visible to the naked eye of an observer.

A flock of intelligent autonomous unmanned aircraft will resemble a starling murmuration, a few hundred seemingly leaderless birds moving as one, turning and twisting to avoid an adversary as they seek their target. Likewise, a school of underwater unmanned vehicles will resemble a pod of dolphins piloting the bow of an aircraft carrier through the sea.

And if we had the ability to see in the radio frequency spectrum, we would see a suite of radios changing color while sliding through the spectrum, their signals getting larger or smaller as power increases and decreases, or changing form altogether as they shape shift between wave-forms. It is a shame we will never see radio and radar signals cooperatively sharing spectrum while avoiding a radio telescope and satellite up-link and down-link beams. It would be spectacular.

Understanding the behavior of intelligent autonomous systems is a challenge regardless of whether a system is made up of living and breathing animals or machines with artificial intelligence. For example, the behavior of a single bison is very different from that of a herd of bison.

Fish behave differently if they are schooling or shoaling. Schooling fish will not only swim closely together, they will form a very tight formation and will swim in a very synchronized manner. In contrast, schoaling fish stay together for social reasons, such as defense against predators, better feeding, and higher success in finding a mate.

In other words, shoals are simply aggregations of individuals; schools are shoals exhibiting polarized, synchronized motion. In shoals, no single individual controls the group and yet the group has its own behavior. Even when the behavior of an individual appears chaotic, the group appears to behave as a coordinated entity.

The same will be true of interconnected intelligent autonomous systems. No single controller device will have the ability to maintain situational awareness of every node in an infinitely complex continually morphing system. Devices will have certain behaviors controlling their own actions as individuals, and they will have other behaviors intended to enhance their abilities to cooperate in a group. Some of these behaviors may be by design; others will be learned over time. Some learning might only be shared among other members of the group; other knowledge may be shared widely among all who can use it.

We should also consider the reality that all interconnected intelligent autonomous system behavior won't be benign. A lumbering herd of wildebeests can quickly become a stampede. Individuals can perceive a situation that warrants caution, but a lone response can set off a chain reaction and panic can spread through the group; all of which may be artificially induced through some outside source. Herd, school or flock behavior, intended to protect members of the group, transforms and begins to operate at the expense of individuals. Predators may intentionally stampede their prey over a cliff just as an adversary may harm interconnected intelligent autonomous systems.

What does this mean as far as where the future takes us? We have lived alongside interconnected intelligent autonomous systems for millennia. Humans have learned to understand natural flocking, schooling, and herding behavior in animals of all species. We used this knowledge to become the dominant species on our planet. In the coming decades we will learn to understand this behavior among artificial systems as well. And nowhere is this behavior going to be stranger or more fascinating than in interconnected intelligent autonomous spectrum-dependent systems moving through the electromagnetic environment.

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42

Radio 2050

It can be embarrassing to attempt to predict technology beyond its current development horizon. This is especially challenging when the technology has begun to accelerate exponentially. To predict the future of radio into the second half of the 21st century, we will need to look back at its development from a 19th century oddity, to a 20th century necessity, and into the early years of the 21st century.

The expansion of Maxwell's electromagnetic theory of light by Heinrich Hertz in 1886 starts our timeline.

Radio's first 50 years saw the technology move out of the laboratory and into society.

By the mid-1930s, radio, television and radar had become the cutting-edge technology of the day. However, another technology was also in development that would not only eclipse radio as the icon of the future, but would forever change the way radio technology is employed in society.

This development, the computer, changed the fundamental building blocks of radio hardware. And it is that marriage of computer to radio that is having the greatest impact on radio's second century.

It has been said of technology that “form follows function.” But when the function is formless an interesting opportunity for integration occurs.

In the later years of the 20th century, the function of producing radio waves moved out of the physical dimension of tubes and transistors to become a function of software and microchips. Today’s wireless technology is a chipset capability and no longer a proprietary device.

While we will always have legacy technology, somewhere someone is still making buggy whips, the future of radio is to disappear into an integrated interconnected fabric of the world around us.

Within the next decade, radio technology will enable the wireless exchange of information among systems ranging from household appliances to automobiles. The per unit cost of wireless nodes will continue to drop while their capabilities will continue to increase. Lower cost devices will lead to their integration in diverse and unexpected ways.

As we head into the middle of the 21st century we won’t be surprised to find that more of our devices are interconnected than are not. Taking a studied look around the typical office or home, we find countless items that will interact with each other in much the same way that we interact with them today.

Where today, a human looks for wear and tear in home or office equipment; in 2050, a device will not only know its level of wear but will communicate with other affected items to manage its deficiencies.

Perhaps our transportation systems will communicate with other systems or devices to optimize our experiences or minimize their impact on our environment.

And the knowledge we collect may interact with the collective knowledge of our friends, family, co-workers, and their devices to anticipate capabilities we may not know we need until they are presented for our use.

While total interconnectivity throughout our environment is unlikely, the ratio of inter-connection to disconnection will be much higher than it is today. All this interconnection will be done wirelessly. Physical connections will be seen as cumbersome and antiquated.

But the radio, as a unique device, will have all but disappeared into the products themselves.

By January 2050, the typical consumer will assume a device is capable of wireless interconnectivity and will be surprised when it isn't.

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43

The Evolution of Infrastructure

All roads lead to Rome. Since ancient times, infrastructure has been the keystone to civilization. At its core, infrastructure is transportation. Infrastructure transports people, clean water, food, and power into our lives and infrastructure transports sewage and garbage safely away. Modern civilizations are the result of infrastructure development.

How has infrastructure evolved, and what could it encompass in the future?

Innovations in infrastructure are typically built alongside, or integrated into, existing infrastructure. Transportation was first built on the natural infrastructure of rivers. Roads soon followed. Sewage and clean water systems were often built under roads. In addition, in the 20th century, infrastructure expanded to encompass electricity and telecommunications grids.

Most infrastructure is built on a hub-spoke architecture. Paths went to and from the village. Roads went from the villages to the city. Few infrastructures are truly point-to-point. In the 20th century, every house had a telephone wire connecting it to a switching hub which then connected to other houses. The same is true for modern wireless communications network design. Today, cellular networks are still built around this hub-spoke architecture but without a dedicated physical line to each device.

While infrastructure is the foundation on which human civilization is built, it is also the vulnerability by which many have fallen. Without a reliable infrastructure, civilizations cannot endure. This is true for military infrastructure, as well as civil.

For a mobile military, maintaining its internal infrastructure while integrating into coalition and a host nation's infrastructure is an exceptionally complex challenge. A modern carrier strike group is comparable to a mobile floating city with several airports. Each ship is a village with power, sewage, and communications requirements. Nearly all of these services depend on electricity.

In addition to obvious uses, such as light, heat, and communications, many other electrical systems may not be so apparent. Large ships operate much the same way a diesel locomotive uses its diesel engine to drive a generator and produce electricity which then powers an electric motor to turn the propellers. Even advanced nuclear-powered submarines and aircraft carriers are, at their core, electric vehicles.

It is hard to imagine a world without electricity. Brief interruptions in electrical power can send a city into turmoil. Long-term power disruption, for months or years, is the stuff of post-apocalyptic novels.

For deployed military, and particularly ships at sea, our modern land-based electrical infrastructure, the power grid, is inaccessible. Power must be generated locally. Moreover, as a result, fuel for power production must be transported across oceans and hostile areas to where the power is produced to support our Sailors and Marines.

Futurists speculate this may change by the middle of the 21st century. Along with high efficient solar and wind systems, it will also be practical to transmit power wirelessly. Similar to satellite communications, begun in the mid-20th century, satellite power distribution may become reality in the mid-21st century.

Combining wireless power transmission with ultra-high efficient batteries and capacitor-based storage will reduce, and in many cases, eliminate, the cost and challenge of transporting fuel to produce electricity.

Wireless power infrastructure will prove to be a radical transformation. Similar to the current wireless telecommunication revolution, the traditional power grid infrastructure will be simultaneously challenged and enhanced by dynamic wireless solutions. Strings of power poles and high tension power lines dotting the landscape may become a rare sight.

Global access to electricity will enable migration to new geographic areas, reducing population concentrations and related congestion. The ability to deliver power without costly and complicated infrastructure will be an advantage to the nearly 2 billion people currently living without electricity. In time, this technology will also enhance Navy and Marine Corps operations.

As with each advance in infrastructure, wireless power infrastructure will open new opportunities for human civilization.

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44

Spectrum Unification

The United States uses a bifurcated process to manage its electromagnetic spectrum resources. The National Telecommunications and Information Administration (NTIA) manages spectrum for federal government users, including the military departments of the Army, Navy and Air Force. The Federal Communications Commission (FCC) manages spectrum for non-federal users, including state and local governments, commercial industry, and private citizens. Two separate agencies manage one common resource. In this article, we address the option of the unification of the electromagnetic spectrum while maintaining the protections of bifurcation.

In its simplest form, spectrum management is accomplished by allocating separate parts of the spectrum to either federal users or non-federal users. For example, a frequency band is allocated exclusively for federal users, while the next frequency band is allocated exclusively for non-federal spectrum users. The subsequent frequency band is again allocated to federal users. Alternating the frequency bands between federal and non-federal users is a simple method of sharing the electromagnetic spectrum.

Other bands of the radio frequency spectrum are allocated to both federal and non-federal users, but for different purposes. For example, the band is allocated for federal radar users and for non-federal amateur radio operators. In this example, federal operators may have primary access over non-federal operators. In other shared bands, non-federal users have primary access over federal government users; and in other bands, primary and secondary operations are allocated to both federal and non-federal users.

These are indicated within the national Table of Frequency Allocations from the Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook), by specifying the operations in all upper case letters for primary, or a mix of upper and lower case letters for secondary allocation.

Spectrum unification, where both federal and non-federal users have equal access to the spectrum, is currently in place within the United States in several frequency bands. For example, a band is allocated for both federal and non-federal aeronautical telemetry. Within the allocation table, unified bands are easily identified since there is no line dividing federal and non-federal allocation. The band is already unified.

In other bands which are currently allocated exclusively for federal use, or which shows the bands currently allocated exclusively to non-federal use, unification may be as simple as allowing equal access by both federal and non-federal users. These bands would be unified by removing their exclusivity.

In bands where both federal and non-federal users share access, but one user has additional services allocated, it may be practical to merge the allocation and enable both federal and non-federal systems access to all allocations. Or, in cases where there is a need to limit allocation, the restriction could be changed from an allocation to a footnote.

For example, many frequency bands contain footnotes that apply only to Federal (G) or non-Federal (NG) operations. Versions of these types of footnotes could be used to provide specific restrictions or protections if the spectrum transitions to unification.

These footnotes could also be used to maintain the full effect of bifurcation while still enabling full spectrum unification. Examples of these type footnotes are currently used to further limit spectrum allocations within either a federal or non-federal exclusive frequency band. For example, while some frequency bands may be allocated for federal use, the footnote G27 further allocates access specifically to military operations. Similar footnotes could be applied in those unique circumstances where it would be necessary to maintain the protections of bifurcation within a unified spectrum.

This article is not intended to advocate either for or against spectrum unification. A total shift from spectrum bifurcation may not be practical. However, as summarized in this article, much of the spectrum is nearly unified today, and with a measured approach, the electromagnetic spectrum could be further unified.

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45

The Road to Real-time Frequency Spectrum Sharing

Simply stated, frequency management is the process of acquiring authority to operate a particular device at a location on a frequency under specific technical parameters, while spectrum sharing is a complex process intended to assure the best possible use of electromagnetic spectrum.

There are many ways to share spectrum, and continually emerging technology will enable even greater sharing. What is limiting the implementation of these technologies is our century-old frequency management process designed to permanently assign one frequency to one system at one location for one use.

A frequency license grants holders certain rights critical to their business or operational plan. Whether air traffic control or emergency communications, the license holder is assured protection from harmful interference.

Improving the Frequency Management Process

The focus of this article is how to maintain protections assured by a traditional frequency license, while sharing the frequency spectrum among multiple users in real-time.

In 2014, acquiring a frequency assignment, the federal equivalent to a frequency license, took approximately 10,000,000 seconds (more than three months). We will use this as our baseline for improvements marking the milestones along the road to real-time spectrum sharing.

While there is no true "real-time" technology, for the purposes of our journey we will set a goal of sub-second frequency management as near enough to real-time as would be needed for real-time electromagnetic spectrum sharing. Along our journey, we will discuss how frequency management will migrate from a people-centric manual process to a trusted autonomous capability.

Improving any process is a challenge. Reducing a process time as many as seven orders of magnitude, from 10,000,000 seconds to one second, is unobtainable in any traditional process improvement methodology. The longest journey begins with the first step. The journey to real-time spectrum sharing will take many steps and pass several critical milestones. To reach our goal, we will make improvements one step at a time, five steps in all. Because frequency management is a process, our journey will be made through a series of process improvements. Each step in reducing processing time signifies one or two orders of magnitude of improvement.

Spectrum Sharing Milestones

The first milestone process improvement is achievable through aggressively streamlining current information workflows. Where current frequency management processes require three months to replace one frequency with another, by

2021 this process will be reduced to three days. Spectrum managers will rely on automated tools to reduce validation steps and minimize rework. Subject matter expert coordination will be initiated through an automated review of license requests. Most licenses will be issued without any intermediate reviews or intervention.

The second major milestone for real-time spectrum sharing is in 2029, with the reduction of frequency processing time from three days to just three hours. While this is not yet real-time, a three-hour spectrum sharing timeframe will enable systems to share spectrum based on usage trends throughout the day. Changing frequencies several times per day will require greater reliance on machine-to-machine communications with only the most exceptional coordination requiring subject matter expert intervention. Most licenses will be requested and issued without any human intervention.

Total process automation, our third milestone, will be reached in 2037 when the typical frequency assignment processing time is reduced from three hours to three minutes. Systems will continually self-evaluate their spectrum requirements. Based on their anticipated frequency usage, they will request new frequencies and release old frequencies to satisfy near-term spectrum usage requirements. Localized frequency sharing will contribute to reduce process time by reducing reliance on centralized licensing. In individual systems, licenses will be granted and maintained from a centralized system based on local analysis.

Passing the fourth milestone in 2043, reducing the process timeline from three minutes to three seconds , will mark the majority of frequency assignment processes shifting from centralized to decentralized licensing. Local frequency management systems will issue licenses based on mutually accepted rules for protection criteria. Incidents of harmful interference will be exceptionally rare as systems will continually evaluate and anticipate frequency requirements and acquire frequency licenses on demand.

Following this path, the fifth milestone and final destination of real-time spectrum sharing will be reached around 2050. Systems will retain full-licensed rights to their frequency assignment when required, and release all rights from the frequency assignment when no longer required. For practical purposes, when frequency assignments are traded in and out of systems in less than one second, licensed radio frequency spectrum will have become a real-time shared resource.

On the Horizon

This article did not address technological milestones because most readers will note regulatory processes inevitably lag behind technological innovation. Technology to implement real-time spectrum sharing exists in 2014, or is on horizon. This article considered what changes will take place to frequency management processes that will provide these systems near real-time access to spectrum on demand, while maintaining their current licensed spectrum rights and protections.

To some readers, our journey from traditional frequency management to real-time spectrum sharing has taken far too long, more than 35 years. Other readers will note that every one of the five major milestones along the way is a heroic effort in its own right, each reducing process timelines by 90 or 99 percent. All readers should recognize that real-time spectrum sharing will be the result of extraordinary changes in modern frequency management processes.

THE ROAD TO REAL-TIME FREQUENCY SPECTRUM SHARING

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46

National Radio Quiet and Dynamic Zones

Across the United States, radio transmitters and receivers are protected from interfering with each other through standardized rules overseen by the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA).

Under normal circumstances, with normal radio transmitters and receivers, this method of protection works quite well. However, some radio transmitters and receivers are far from normal.

Some radio receivers are incredibly sensitive. For example, radio telescopes can receive faint signals from billions upon billions of miles in space. For special receivers there are special areas set aside to protect them from "normal" radio transmitters. The National Radio Quiet Zone (NRQZ) is an area where special rules have been established to protect these special receivers from normal radio transmitters. Signals from normal transmitters like cell phones, television broadcasts, and even microwave ovens, are restricted or prohibited within the

National Radio Quiet Zone. These special rules have been established by NTIA to protect the special receivers inside the zone from normal transmitters outside the zone.

Radio transmissions are heavily restricted within the NRQZ by law to facilitate scientific research and military intelligence. The first NRQZ was located in a remote corner of West Virginia; others are in Virginia and a tiny part of Maryland. More are planned in similarly remote locations.

While a quiet zone protects special receivers inside the zone from normal transmitters outside the zone, a dynamic zone does the exact opposite. A National Radio Dynamic Zone would protect normal receivers outside the zone from special transmitters inside the zone. Special transmitters include directed energy systems, high power microwave transmitters, and experimental systems pushing the boundaries of radio technology.

Much like quiet zone rules determine what power levels may cross into the zone, dynamic zone rules determine what power levels may escape from the zone.

The United States does not currently have a National Radio Dynamic Zone. However, when authorized, a special transmitter that would typically function in a dynamic zone may be granted authority to operate on a case-by-case basis, typically during limited times and under stringent restrictions to protect normal radios in the area.

Despite the appearance of performing completely opposite functions, the management of quiet and dynamic zones is very similar, as each manages the strength of a radio signal as it crosses each zone's boundary. And, since both require measuring or calculating the signal strength at the boundary, the hardware and software, like the management principles, are nearly identical.

Quiet and dynamic zones are needed because coordinating every conceivable radio frequency protection scenario would be impossible. Imposing transmitter and receiver restrictions on a case-by-case basis would also be impossible, as would policing interference between normal and special radio systems. And, if not impossible, these scenarios would be prohibitively expensive.

There have been encouraging conversations within the United States recently about establishing a National Radio Dynamic Zone along with additional National Radio Quiet Zones. The Department of the Navy will continue to work with the National Science Foundation, the Federal Communications Commission, and the National Telecommunications and Information Administration to make these special zones a reality.

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